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ABBREVIATIONS. — P = Paper; D = Discussion; I = Illustrated.
Names of authors of papers, etc., are printed in *italics*.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

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NEW DATA ON THE WEIGHT OF A CROWD OF PEOPLE.

BY LEWIS J. JOHNSON, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, December 21, 1904.*]

THE weight of a crowd of people is one of the most important bits of data used by the structural engineer. It would seem to be one of the most easily determined, yet it is one on which the authorities differ widely, and one which they understate and, with few and unfamiliar exceptions, seriously understate. The engineering practice of both Europe and America accords closely with Trautwine's recommendation.

> "On bridges for turnpikes and common roads, no probable contingency could crowd people to such an extent as to weigh more than 80 lbs. per sq. ft. of floor; and this may safely be taken as the maximum load on spans of 20 or more feet. To compensate, however, for impact, we recommend to adopt 100 lbs. as the limit for crowds."†

In a footnote on the same page, Mr. Trautwine cites experiments in support of the preceding, as follows:

> "The engineers of the Chelsea bridge, London, *packed picked* men upon the platform of a weigh-bridge, with a result of 84 lbs. per sq. ft. Mr. Nash, architect of Buckingham Palace, *wedged* men together as closely as they could possibly stand upon an area of 20 ft. diameter; the last man being lowered down from above, among the others. Result, 120 lbs. per sq. ft."

While 80 to 100 lbs. per sq. ft. are generally accepted as the maximum for bridge-work, the city building laws of this country specify 80 to 150 lbs. for the minimum floor loads for public as-

* Manuscript received December 31, 1904.—Secretary, Ass'n of Eng. Socs.

† Civil Engineer's Pocket Book, 18th edition, p. 726.

sembly rooms—some cities naming the lower value, others the higher, and others still giving intermediate values.

Why the proper assumptions for buildings have been commonly held at a higher figure than for bridges, it is not easy to say. Perhaps it is because the increased cost of the building by leaving a larger margin is relatively a less serious matter than with a bridge, and the incentive for close figuring is relatively less felt. An additional factor may be that the likelihood for defective construction may have been regarded somewhat greater in the cases of buildings than with bridges. There may be other causes. It certainly does not seem attributable to any current belief that the weight of crowds might reach 150 lbs. per sq. ft., for such a belief would certainly have been definitely stated somewhere and would have been felt in bridge practice.

However this may be, the writer has been slowly coming to distrust the correctness of prevailing ideas on the whole subject, and for some months past has been making experiments in the attempt to get some first-hand information. The men at his disposal were his own students of engineering, and their patient and intelligent interest has alone made the work possible. The results up to last April were published,* and accompanying them a series of nine extracts from writers of various countries. The writer had at that time obtained a maximum result of 156.9 lbs. per sq. ft., due to 67 men averaging 151.5 lbs. each in a space of 64 sq. ft., and this is what was published. The authorities quoted in the nine extracts gave some 80, some 120 lbs. per sq. ft. as the maximum possible from a stationary crowd, one only going above 120. Mr. Stoney reported that he got 147.4 lbs. per sq. ft. from 58 Irish laborers, averaging 145 lbs. each, packed into a space of 57 sq. ft. It was observed that the authorities, with the exception of Stoney, rarely cited any deliberately conducted experiment. The best-known experiments are those quoted by Trautwine and given above. Stoney's seem to have been generally overlooked.

The result published last April was roughly verified† by Professor Spofford, of the Massachusetts Institute of Technology, and later by Herr Hunscheidt in Bonn.‡ These gentlemen reached results of 142.5 and 144 lbs. per sq. ft., respectively, each making it clear that the limit had not been reached. In the discussion that

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* *Engineering News,* April 14, 1904, p. 360.

† *Engineering News,* May 5, 1904, p. 426.

‡ *Zentralblatt der Bauverwaltung,* October 8, 1904, and *Engineering News,* November 3, 1904, p. 406.

followed, the results of Professor Kernot, of Melbourne, were recalled. He reported* 143.1 lbs. per sq. ft. as his maximum.

The writer gave the matter no further attention till within the last few weeks, when two of the foremost American structural engineers publicly expressed their belief that a load from a crowd of people in buildings in excess of 40 to 45 lbs. per sq. ft. is not exceeded in practice often enough to demand much consideration.

One of these gentlemen, Mr. C. C. Schneider, stated:†

> "A live load of 40 lbs. per sq. ft. . . . may be considered the maximum load to be provided for as a distributed load for all floors on which crowds of people may be expected to congregate, such as all kinds of rooms in dwelling houses, apartment houses, hotels, office buildings, schools, churches, theaters, concert halls, ballrooms, drill rooms, etc."

Further on, to allow for vibrations in the case of ballrooms, drill rooms, gymnasiums,‡ etc., he recommended assuming an additional 40 lbs. per sq. ft., after stating that

> "a uniform load of 40 lbs. per sq. ft. will scarcely ever be exceeded by a crowd of people."

Mr. Theodore Cooper,§ in supporting Mr. Schneider's assumption of 40 lbs. per sq. ft. and in illustrating the rarity of a load above that figure, says:

> "Most people have experienced the discomforts of a crowded Elevated Railway car when not another person can be squeezed inside of the gates. Such a crowd, numbering about 120 persons and not weighing more than 18,000 lbs., is contained in a space of about 400 sq. ft., including platforms, or 45 lbs. per sq. ft."

In view of these statements, the time seemed appropriate for further work on the problem, and for the sake of taking part in the discussion with Messrs. Schneider and Cooper, the writer had a series of photographs taken showing bird's-eye views of crowds (in a space 6 ft. square) at different degrees of compactness from about 40 lbs. per sq. ft. to about 150. These photographs are reproduced in Figs. 1 to 8, and are sufficiently explained by their titles. Special attention may be called to Figs. 1, 2 and 3 as representing crowds approximating Mr. Schneider's 40 lbs. per sq. ft. and to Fig. 4 as showing a crowd somewhat *more* compact than Mr. Cooper's Elevated Railway crowd.

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* *Engineering News*, March 16, 1893, p. 252.

† *Proceedings American Society of Civil Engineers*, September, 1904, vol. xxx, p. 676.

‡ *Ibid.*, p. 680.

§ *Proceedings American Society of Civil Engineers*, November, 1904, p 851.

In Fig. 3, the men are in an alcove four feet square. Specially light men were selected for this test for the sake of showing a specially crowded example of 40 lbs. per sq. ft. One less man, if the average were 160 lbs. each, would produce the requisite 40 lbs. with considerably less appearance of crowding.

In Fig. 7, the very high average weight (167.7 lbs. per man) is due to the fact that the crowd shown is the remnant of the crowd of Fig. 9 after twelve of the lighter men near the gate had left the box.

In all the experiments in close crowding, the men were, up to this time, left to arrange themselves.* They naturally stood entirely at random, facing in all directions.

Obviously, the next step was to see what could be reached by facing the men all one way, especially as they would be likely to be so arranged in a constriction in a street caused by a drawbridge or in standing in a crowded meeting. At the same time some care was taken to select tall men, with a view to finding out what a crowd actually might weigh. The result, to the writer's great astonishment, was on the first trial of this process 176.4 lbs. per sq. ft., due to 40 men in a space 6 ft. square. A repetition of it for sake of a better photograph and somewhat better selection of the men was made. The result (Fig. 9) was 181.3 lbs. per sq. ft., due to 40 men, averaging 163 lbs. each, in a space 6 ft. square. This result is, of course, an extreme, evidently to be put in the same class with the 84 lbs. and 120 lbs. in the quotation from Trautwine. The great increase in the results of this fall over those of last spring seems to be due largely to the better economy of room from facing the men all one way and partly to the dimensions of the box being such as to work up with little waste room, both of which are conditions favoring congestion to be met in practice.

Though 181 lbs. per sq. ft. must be conceded to be an extreme, it is believed that something very close to that figure is reached over the whole drawbridge on the way from Soldiers' Field to Harvard Square after one of the great football games.

Moreover, if 40 men, averaging 163 lbs. each, can stand in no serious discomfort in 36 sq. ft., it is clear that 40 men of the ordinary size of 150 lbs. each could easily do so. The result then would be 166.7 lbs. per sq. ft.

The conclusion seems irresistible that loads of 180 lbs. per sq. ft. may actually occur in exceptional cases; that 160 lbs. must frequently occur; that 140 lbs. must be common on station platforms, in corridors and many other places frequented by throngs of people;

* Except in Fig. 7, which, as just stated, was taken after Fig. 9.

FIG. 1. 41.8 LBS. PER SQ. FT.
(10 men, averaging 150.6 lbs., on 36 sq. ft.)

FIG. 2. SAME MEN AS IN FIG. 1. DIFFERENTLY SPACED.

FIG. 3. 41.8 LBS. PER SQ. FT.
(5 men, averaging 133.8 lbs., on 16 sq. ft.)

FIG. 4. 47.2 LBS. PER SQ. FT.
(11 men, averaging 154.6 lbs., on 36 sq. ft.)

FIGS. 1-4. CROWDS WEIGHING 41.8 AND 47.2 LBS. PER SQ. FT.

FIG. 5. 83.7 LBS. PER SQ. FT.
(20 men, averaging 150.7 lbs.)

FIG. 6. 100 LBS. PER SQ. FT.
(24 men, averaging 150 lbs.)

FIG. 7. 130.4 LBS. PER SQ. FT.
(28 men, averaging 167.7 lbs.)

FIG. 8. 154.2 LBS. PER SQ. FT.
(37 men, averaging 150.1 lbs.)

FIGS. 4-8. CROWDS WEIGHING BETWEEN 80 AND 155 LBS. PER SQ. FT., OCCUPYING IN EACH CASE A SPACE OF 36 SQ. FT.

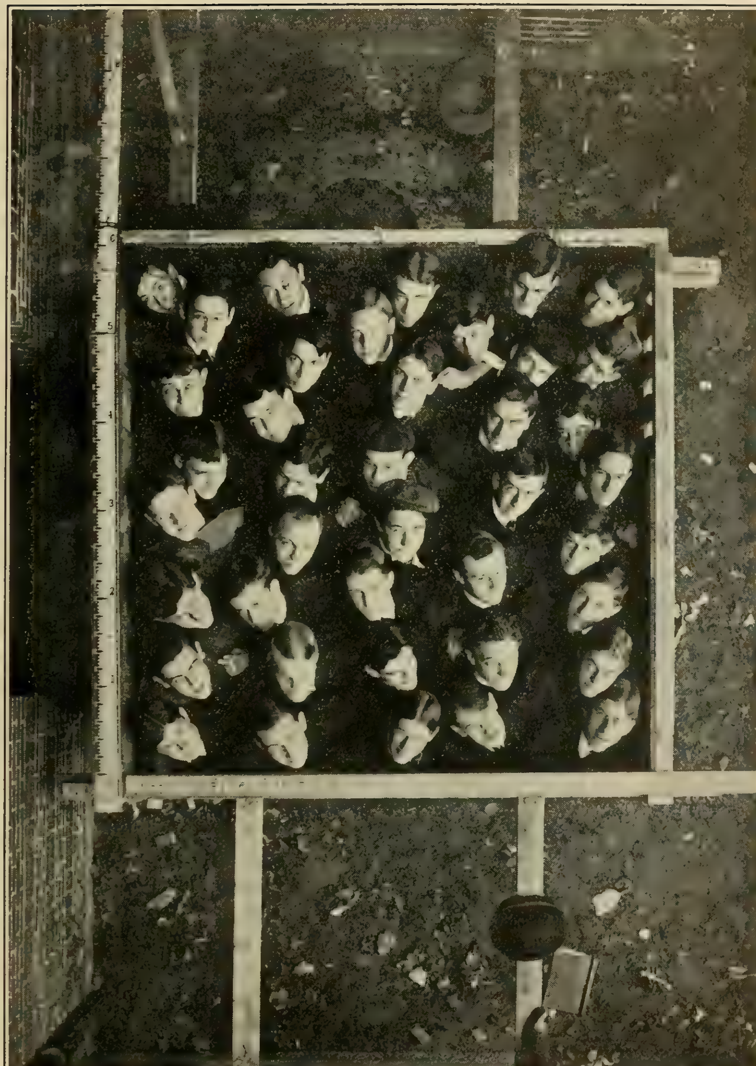


Fig. 9. 181.3 Lbs. per Sq. Ft.
(40 men, at 163.2 lbs. average, on 36 sq. ft.)

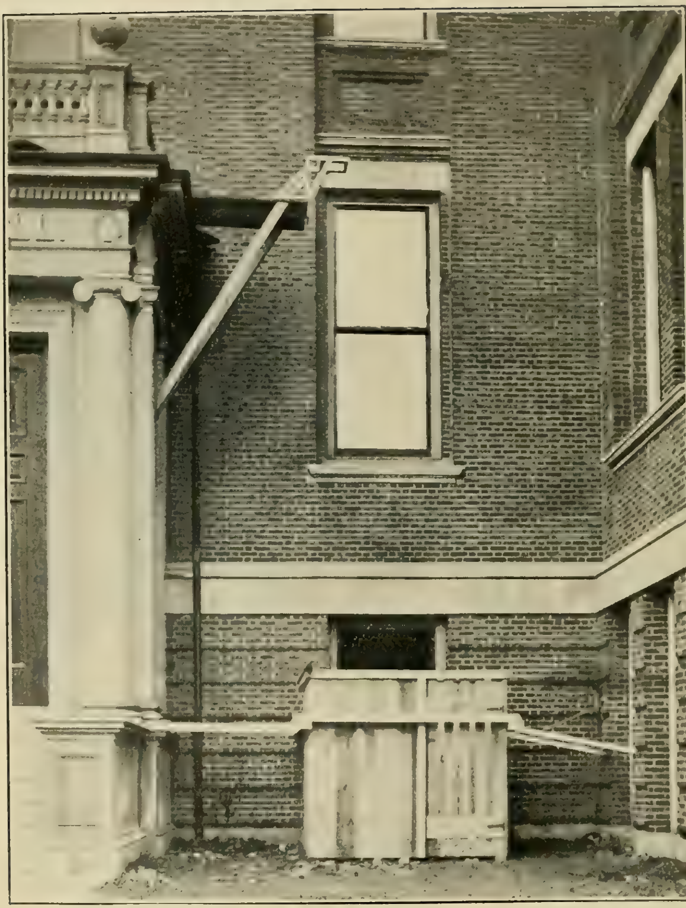


FIG. 10. APPARATUS USED IN PHOTOGRAPHING CROWDS FOR THE DETERMINATION OF FLOOR LOADS.

that 80 lbs. per sq. ft. must be common at social gatherings in private houses. The conclusion is equally clear that the margin of safety in many existing structures designed for 80 to 100 lbs. per sq. ft. (to say nothing of 40 to 45) must be much less than has been supposed. Probably the correct inference is that the experience of many years in many lands has demonstrated that the margin has been sufficient, nevertheless. Even if that be true, it is no reason why we should remain in the dark about how much a crowd of people actually does weigh. It is only with the correct knowledge of the maximum that engineers can intelligently decide for what load any part of any structure may properly be proportioned. In thus deciding, it will not be forgotten that a crowd of people is the very last load which should be endangered by too small a margin of safety even "once in a great while."

Fig. 10 shows the box or pen in which the men gathered (after being weighed inside the building) and the scaffolding on which the camera was mounted. The lens was pointed directly downward. The men entered the box through the gate at the right, and when the box was full the gate was closed and secured by the heavy bar shown. The braces running to the side of the porch and the wall of the building were for strengthening the box against internal pressure, which, with forty men in the inclosure, became considerable —especially when they took it into their heads to take a long breath simultaneously. The men were requested to look up toward the camera, so as to be more easily distinguishable for counting, and so as to be identifiable as a check upon the records.

It may be interesting to add that what may be called the asymptotic value of the weight of a crowd of men must be about 218 lbs. per sq. ft. (possibly more than this rather than less with men of varying height). This figure was reached upon examination of data kindly furnished by Dr. Sargent, Director of the Harvard Gymnasium. It was obtained by dividing the weight of a man 6 ft. 3 in. tall, a former football captain, by his maximum horizontal cross-section as obtained by a planimeter. This maximum section was, of course, through the chest, including the arms. The weight of this man was 177 lbs., and maximum cross-section 117 sq. in., both quantities exclusive of clothing.

In closing, the writer takes pleasure in thanking not only the students who cheerfully submitted to the packing process, but also many colleagues and friends who rendered much assistance, and particularly Mr. E. E. Pettee, Assoc. M. Am. Soc. C. E., and Mr. N. E. Olds, who took the photographs.

DISCUSSION.

Prof. C. M. Spofford.—Having been somewhat surprised by the unexpectedly high values reached by Professor Johnson in preliminary experiments upon the weight of crowds, the speaker undertook to check these results by ascertaining how heavy a live load he could obtain on his office floor. In order to do this he packed into the room a crowd of students taken at random from the three upper classes of the Massachusetts Institute of Technology. The area of the room used was 87.3 square feet gross, no deduction being made for several projections which interfered somewhat with the closest possible packing. After 83 men had entered, the supply immediately at hand became exhausted and no effort was made to find others, although there was room for several more near the door, and a systematic packing of those in the room would probably have provided still more free space. The total weight thus obtained was 12,443 lbs., an average of 149.9 lbs. per man and of 142.5 lbs. per sq. foot of floor.

Although the crowd just described was very dense, the conditions were apparently no worse than obtain occasionally at points of great congestion. For example, during the recent convention of the Grand Army at Boston, the illumination of the Public Gardens was one of the sights which everybody wanted to see. As a consequence the foot bridge there was frequently packed with a crowd of such a density that the average load per foot upon the entire bridge must have at least equaled the above figure.

The photographs shown by Professor Johnson furnish such a complete refutation of the theory that it is only in extreme cases that the weight of a crowd can reach as high a figure as 80 or 90 lbs. per sq. ft. that the speaker hopes that no writer will again advance these figures as extreme limits.

RECENT WORK IN UNIFYING SPECIFICATIONS FOR ENGINEERING MATERIALS.

By J. Parker Snow, Member Boston Society of Civil Engineers.

[Notes of a talk at an informal meeting of the Society, December 7, 1904.*]

An earnest effort is being made by many scientific associations to unify and modernize the requirements for structural materials, and to bring out the best practice in the use of these materials in construction. The object of this description is to lay before those interested, some of the work being done on these lines in this and other countries. The American Railway Engineering and Maintenance of Way Association is one of the organizations whose object is pre-eminently the accomplishment of the above results.

This Association is composed largely of railroad and municipal engineers, together with many engineers of manufactories and a fair sprinkling of college professors and consulting engineers. The work of the Association is done by standing committees whose personnel is changed somewhat, but whose work is continuous from year to year.

There are at present 16 committees on the following subjects:

I Roadway.
II Ballasting.
III Ties.
IV Rail.
V Track.
VI Buildings.
VII Wooden Bridges and Trestles.
VIII Masonry.
IX Signs, Fences, Crossings and Cattle-guards.
X Signaling and Interlocking.
XI Records, Reports and Accounts.
XII Uniform Rules, Organization, Titles, Code, etc.
XIII Water Service.
XIV Yards and Terminals.
XV Iron and Steel Structures.
XVI Economics of Railway Location.

The Society was organized in 1899, and the first formal meeting was held in March, 1900. The headquarters of the Association are at room 1562 Monadnock Building, Chicago, Ill., and the annual meetings are held there in March of each year.

* Manuscript received January 23, 1905.—Secretary, Ass'n of Eng. Socs.

Three of the committees, I, IV and XV, have submitted specifications on roadway, rails and iron and steel structures. These specifications are printed in pamphlet form and are on sale at a nominal price by the Secretary.

The specification compiled by the Committee on Iron and Steel Structures was adopted by the Association in 1903, and covers material and workmanship for railroad bridges. The grade of steel recommended in this specification is called structural steel, having a range of ultimate strength from 55,000 to 65,000 lbs. per sq. in. Since the adoption of this specification the Committee has been engaged in extending its scope, and will present to the Association, at the coming annual meeting, schedules covering a few amendments to the adopted specification; a specification for details of design; impact allowance; live loads; specifications for special metals; unit strains and proportion of parts; and general features, together with reports on an extensive series of experiments on riveted joints and on punching and reaming, and a historical sketch of the development of the American bridge specification.

The aim of the Committee has been to compile a specification that is general enough to cover all ordinary railroad bridges, and, at the same time, in sufficient detail to guide experienced designers to uniform results.

The American Society for Testing Materials, a society composed of engineers and manufacturers, which does its work largely by means of standing committees, something on the same lines as the Maintenance of Way Association, has a large Committee on Standard Specifications for Iron and Steel (Committee A), which has lately approved the specification for structural steel adopted in 1903 by the Maintenance of Way Association. This Society has done and is still doing a great deal of work in unifying the requirements for all classes of materials used in construction; having committees as follows:

A Iron and steel.
B Cast Iron.
C Cements.
D Paving and building brick.
E Preservative coatings for iron and steel.
F Heat treatment of iron and steel.
G Magnetic properties of iron and steel.
H Road materials.
I Reinforced concrete.
J Foundry coke.
K Methods of testing.

L Sewer pipes.
M Stay bolts.
N Lubricants.
O Uniform speed of commercial testing.
P Fireproofing materials.
Q Grading of timber.

Committee B, consisting of 67 members, has lately reported a series of specifications filling 12 large pages of print and covering the following varieties of cast iron: foundry pig iron; cast-iron pipe and special castings; locomotive cylinders; cast-iron car wheels; malleable castings, and gray iron castings.

Committee C is acting jointly with Committee VIII of the Maintenance of Way Association, the Association of American Cement Manufacturers and a special committee of the American Society of Civil Engineers, in the work of drafting complete specifications for cement and the compounds of which it is the principal factor.

This Society is affiliated with the European International Association for Testing Materials, which is working on somewhat similar lines, but confines itself more particularly to scientific questions of methods of testing, rather than to the formulation of commercial specifications for materials.

A powerful association in England, called the Engineering Standards Committee, has lately been organized to do similar work for our English cousins in a way that is truly British in its thoroughness and completeness.

This organization is supported by the following powerful societies:

The Institution of Civil Engineers.
The Institution of Mechanical Engineers.
The Institution of Naval Architects.
The Iron and Steel Institute.
The Institution of Electrical Engineers.

The British and Indian governments, through the Board of Trade, have granted the committees very substantial financial aid (some $20,000) for the past year; and an equivalent sum has been contributed by the supporting societies.

The work is in the hands of 35 committees working under the direction of a main committee. The object is to standardize practice in all lines of mechanical engineering, and to formulate specifications for all kinds of materials used in construction. Its results cannot fail to revolutionize English engineering. We thus see that

all over the civilized world there is a movement toward uniformity in practice and an interchange of knowledge and experiences. The tendency is toward united rather than individual effort. These associations are comparatively young, the latest and grandest of all, The English Standards Committee, being hardly three years old.

It behooves American engineers to keep posted on the doings of these associations if they wish, in the race of human progress, to keep on the right side of the distance pole.

OBITUARY.

James Thomas Boyd.

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

JAMES THOMAS BOYD was born on November 25, 1845, at Fishkill-on-Hudson, and died on November 3, 1904, at Boston, Massachusetts. He spent the first six years of his life at Fishkill; then his family moved to Newburgh, N. Y., where he entered the public school. He graduated from the Newburgh Academy in 1859, and entered an apprenticeship in the Washington Iron Foundry. There his work was supplemented by instruction in draughting under the foreman of the works. In 1864, he took the examination for engineer in the Navy, and on October 11th was appointed Acting Third Assistant Engineer. His first service was on the gunboat "Dumbarton," then belonging to the North Atlantic Blockading Squadron. In March, 1865, he was transferred to the ironclad "Casco," fitting out at the New York Navy Yard. The close of the war necessitated a great reduction of the military establishment, and Mr. Boyd was honorably discharged from the service on July 31, 1865. He returned to Newburgh and then came to this part of Massachusetts for a position in the draughting-room of the Atlantic Works. With the exception of two short intervals, he was connected with these works during the remainder of his life, either as employee or director. For two years he was away in charge of the chain works at East Bridgewater, and for several years he was in the National Tube Works. From May, 1892, to March, 1895, he was manager of the Blake Pump Works at East Cambridge. In the latter year he opened an office in Boston as consulting engineer, serving in that capacity the Atlantic Works, the Dominion Coal Company, and the Edison Illuminating Company. He was a member of the Boston Society of Civil Engineers from May 20, 1891, to November 3, 1904, and besides he was a member of the following societies and clubs:

The American Society of Mechanical Engineers.

The American Society of Naval Engineers.

The American Society of Naval Architects and Marine Engineers.

The New England Society of Naval Engineers.

The St. Botolph Club.

The Longwood Cricket Club.

He was married on June 25, 1874, to Mary Ellen Fuller, of Lynn, Mass. His wife and one daughter survive him.

While his technical education, like that of most mechanical engineers of his age, was obtained wholly in the draughting-room and workshop, nevertheless his pronounced engineering bent and his long experience in marine work gave him an almost unerring sense in estimating the cost of machinery. He was often associated with Edward Burgess in the design of steam yachts, and he personally designed the machinery for sixty-five vessels of different types. His honesty and uprightness were so well known that on many occasions he held the unusual position of engineer for both parties to a contract. His generous, warm-hearted disposition made him a most agreeable and attractive companion.

Ira N. Hollis,
Frank B. Dowst,
Committee.

Reuben Shirreffs.

Member of the Boston Society of Civil Engineers.

Reuben Shirreffs was of Scotch descent, and was born in Queens County, Nova Scotia, May 26, 1852. His boyhood was passed in the family of his grandfather in Liverpool, N. S., where he attended the high school, which was practically the extent of his educational privileges. The principal of the school and his associates testify in no unmeasured terms to his reputation for promptness, punctuality and thoroughness, traits that were predominant in his after years.

"He never came to the class with an unprepared lesson, and his thoroughness led him to ferret out the very foundation of things, and the whys and wherefores had to be known. For him more than any other pupil extended preparation had to be made by me for the class exercises. His mind was largely mathematical, and the problem had to be more than intricate that his sticktoativeness did not unravel. He was a lad of the highest moral character, without a questionable or degrading habit, and everybody had a good word for him." Thus writes Mr. T. R. Pattillo, his former instructor.

In May, 1872, he became a student in the office of Clemens Herschel, M. Am. Soc. C. E., where he remained until April, 1875. From that date until September, 1879, he was connected with the engineer corps of the Sudbury River Aqueduct, Boston Waterworks, then under construction, as a draftsman, being stationed in the South Framingham office.

The following year he spent with the Chicago, Burlington &

Quincy Railroad as an assistant engineer, and from September, 1880, to June, 1881, he was an assistant with the Holyoke Water Power Company. Leaving Holyoke he went to Richmond, Va., where he was first engineer of water power and afterward engineer of the Richmond & Allegheny Railroad, holding the last named position until February, 1884.

He then became a member of the firm of Stewart, Shirreffs & Co., and for three years was engaged in the building of bridges and other structural iron work. In March, 1887, he took charge of the construction of the new City Hall of Richmond, which, with the rebuilding of the free bridge from Richmond to Manchester, occupied his time until December, 1889.

In January, 1890, he again became associated with Mr. Herschel, and was the Second Assistant Engineer of the East Jersey Water Company, with headquarters at Paterson, N. J., and was employed for some five years upon the design and construction of the long steel-pipe conduits and other works for supplying water to Newark and several other communities in that section.

About this time, Mr. Frederic P. Stearns, M. Am. Soc. C. E., was organizing a large engineering force for the design and construction of the Metropolitan Waterworks system, to provide additional water for the Boston Metropolitan district, and offered Mr. Shirreffs the charge of the designing and drafting department, which he accepted, beginning his duties about October, 1895. While connected with this work he had a large share in the designing of the Wachusett dam, reservoir and aqueduct, the Clinton sewage disposal plant and other parts of the Metropolitan works.

In February, 1899, he resigned his position on this work and returned to Richmond to become chief engineer of the Virginia Electric Railway & Development Company, which position he held until July, 1902, designing, building and equipping a large new steam and water power house, dam and canal at the falls of the James River. Subsequently, in the fall of 1902, he accepted the position of chief engineer of the Great Falls Water Power Company, then contemplating a large development at Great Falls on the Potomac River. The suspension of this work in June, 1904, had a very depressing effect upon Mr. Shirreffs. He died by his own hand in Washington, D. C., on August 31, 1904, the deed being without doubt the result of temporary insanity, induced by overwork and mental strain.

On December 18, 1878, while engaged upon the Sudbury River Aqueduct, he joined the Boston Society of Civil Engineers. He became a member of the New England Waterworks Association

on March 12, 1890, and of the American Society of Civil Engineers on June 4, 1890.

He was married in May, 1884, to Miss Edith Howard, of Richmond, Va., his wife being a member of a prominent Virginia family. She died in the early nineties, and on October 15, 1902, he married Miss Emma Bruce, of Richmond, who survives him.

Mr. Shirreffs was a man of great ability and high ambitions. He was greatly respected by all with whom he came in contact, and he will be sincerely mourned by his former associates, to whom the sad news of his untimely end came as a great shock and brought a deep sense of personal loss.

Alfred D. Flinn,
John C. Chase,
Committee.

Macy Stanton Pope.

Member of the Boston Society of Civil Engineers.

Macy Stanton Pope was born at East Machias, Washington County, Maine, July 26, 1869. He sprung from sturdy New England stock—his father, James Otis Pope, and his mother, Olive F. Chase, both being natives of East Machias. His grandfather was Col. William Pope, a well-known citizen of Boston.

His early life was spent under the good influences of the little town in which he was born. In the shipyards and upon the extensive timber lands owned by his father; upon the chain of lakes and the East Machias River, which flowed past his very door into the ocean but a short distance beyond, he grew up and gained his knowledge of the woods and of the lumber industry—simple and wholesome influences which developed the characteristics of sober thought and sturdy independence, for which he was so marked in life.

He attended the public schools and graduated from the Washington Academy at East Machias on June 20, 1888.

He entered the Massachusetts Institute of Technology in the fall of 1888, and graduated from the Department of Civil Engineering in May, 1892. Although reserved and quiet, he made his influence felt in the cause of good feeling and sense among his classmates, though he rarely appeared as a leader. He was even then mature beyond his years, and his great strength lay in his good balance and sanity of mind, which won the respect of his classmates and the warm friendship of those who knew him well.

Shortly after graduating, he entered the employ of The Associated Factory Mutual Fire Insurance Companies, of Boston, and

the greater part of his time there was spent on a series of tests of cast-iron water pipe and fittings, made at Nashua, N. H., under the direction of Mr. John R. Freeman.

In the fall of 1892, Mr. Pope returned to the Institute as assistant instructor in hydraulic engineering to Prof. Dwight Porter, and he remained there until the following June. He then re-entered the employ of the Factory Mutuals, though a portion of his time was again devoted to the private work of Mr. Freeman, in the preparation of designs for a new reservoir, dam and pumping station for the Pennichuck Waterworks, at Nashua, N. H., and for repairs and improvements upon the water-power plant of the Piscataquis Pulp and Paper Company. From this time until February, 1898, his time was divided between testing work along various lines, in the laboratory of the Factory Mutuals, as well as in the field; to work in the plan department, involving the surveying of mills and the drawing up of plans of them, and private work done for Mr. Freeman. In the latter were included certain investigations relating to the water supplies of New York and Boston.

In February, 1898, under leave of absence from the Company, Mr. Pope returned to his home at East Machias, where he gave his personal attention to his family estate and various allied lumber interests. At this time he also made a trip to the Southern States and California with his mother.

In June, 1900 he returned to the Factory Mutuals, and was employed in making special inspections of mills in different parts of the country. His broad experience in the inspection department of the Factory Mutuals, combined with his own business training, made him a most valuable man for the purpose. He had a strong grasp of the practical bearing of facts, and his ability to sift evidence in making special investigations, even in fields that were new to him, carried conviction. One of his associates happily says, "It is the verdict of all that the work done in each of these various fields was well done, and that the results were received with the fullest confidence by those who used them. In every case strong common sense and a clear appreciation of relative values were predominating characteristics."

Last June, Mr. Pope, feeling the need of rest and change, took a ten weeks' trip abroad. He was not well during the summer, and shortly after his return serious symptoms appeared, which developed into acute Bright's disease, of which, after a month's illness, he died at Brookline, Massachusetts, on December 10, 1904.

Mr. Pope took a deep interest in engineering matters, and was a member of various engineering societies, such as the Boston

Society of Civil Engineers, the American Society of Civil Engineers, the New England Waterworks Association, and the Society of Arts, as well as of the Technology and Appalachian Mountain Clubs.

He was devoted to his old home, and took a warm and active interest in its affairs. For some years he had been one of the Trustees of the Washington Academy at East Machias. He was much interested in its growth and development, and gave financial assistance to it on more than one occasion. His public interest was well illustrated by his liberality in giving to the town, with his two brothers, John A. and Warren F. Pope, a bridge across the East Machias River. This structure, a fine three-span concrete and steel masonry arch, they built as a memorial to the Pope family, and as an object lesson to the town. The memorial tablet upon the structure runs, in part, as follows:

This bridge is Erected in Memory of
William Pope and his sons, William Henry,
Samuel Warren, John Adams, Andrew Jackson,
James Otis, Edwin and George Washington;
Founders of a lumbering and shipbuilding
Business, which began near this site and
Extended to neighboring towns, to Boston
And to the Pacific Coast; And which was conducted
By these men and their descendants from
1807—1901.

His old Alma Mater also commanded Mr. Pope's attention, and he always took a friendly interest in its welfare and progress. In his will he left it the substantial sum of $25,000, while other public bequests were made to the Washington Academy, and various Maine hospitals.

Sound common sense, simple tastes with high ideals, love of work, a just appreciation of nature and a good knowledge of men, were marked characteristics in the life of Macy Stanton Pope, who will long be remembered as a worthy example of a fine and virile type of New Englander.

LEONARD METCALF,
LOAMMI F. BALDWIN,
ALFRED E. BURTON.

ASSOCIATION OF ENGINEERING SOCIETIES.

Articles of Association.

The following Articles of Association were adopted at a meeting held in Chicago, December 4, 1880. At this meeting there were present representatives of the

Western Society of Engineers,
Civil Engineers' Club of Cleveland,
Engineers' Club of St. Louis,

and the

Boston Society of Civil Engineers

was represented by letter.

FOR THE PURPOSE OF SECURING THE BENEFITS OF CLOSER UNION AND THE ADVANCEMENT OF MUTUAL INTERESTS, THE ENGINEERING SOCIETIES AND CLUBS HEREUNTO SUBSCRIBING HAVE AGREED TO THE FOLLOWING

ARTICLES OF ASSOCIATION.

ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be "THE ASSOCIATION OF ENGINEERING SOCIETIES." Its primary object shall be to secure a joint publication of the papers and the transactions of the participating Societies.

ARTICLE II.

ORGANIZATION.

SECTION 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each Society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each Society shall decide, and shall hold office until their successors are chosen.

SEC. 2. The officers of the Board shall be a Chairman and Secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

DUTIES OF OFFICERS.

SECTION 1. The Chairman, in addition to his ordinary duties, shall countersign all bills and vouchers before payment and present an annual report of the transactions of the Board; which report, together with a synopsis of the other general transactions of the Board of interest to members, shall be published in the JOURNAL OF THE ASSOCIATION.

Sec. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the Chairman for counter-signature. He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

PUBLICATIONS.

Section 1. Each Society shall decide for itself what papers and transactions of its own it desires to have published, and shall forward the same to the Secretary.

Sec. 2. Each Society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any Society may be used as it shall see fit. Payments by each Society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

Sec. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

Sec. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions as may be deemed of general interest and value.

ARTICLE V.

CONDITIONS OF PARTICIPATION.

Section 1. Any Society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

Sec. 2. Any Society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

Sec. 3. Any Society may, at the pleasure of the Board, be excluded from this Association for non-payment of dues after thirty days' notice from the Secretary that such payment is due.

ARTICLE VI.

AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating Societies.

ARTICLE VII.

TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall have been ratified by three Societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

These articles were adopted by the several Societies upon the following dates:

Engineers' Club of St. Louis, January 5, 1881.
Civil Engineers' Club of Cleveland, January 8, 1881.
Boston Society of Civil Engineers, January 19, 1881.
Western Society of Engineers, April 5, 1881.

The Board of Managers was organized at a meeting held in Cleveland, January 11, 1881.

The following Societies have since certified their acceptance of the articles, and have become members of the Association of Engineering Societies:

Engineers' Club of Minneapolis, July, 1884.
Civil Engineers' Society of St. Paul, December, 1884.
Engineers' Club of Kansas City, January, 1887.
Montana Society of Civil Engineers, April, 1888.
Wisconsin Polytechnic Society, June, 1892.
Denver Society of Civil Engineers, January 24, 1895.
Association of Engineers of Virginia, February 1, 1895.
Technical Society of the Pacific Coast, March 1, 1895.
Detroit Engineering Society, January, 1897.
Engineers' Society of Western New York, January, 1898.
Louisiana Engineering Society, September 15, 1898.
Engineers' Club of Cincinnati, January, 1899.
Toledo Society of Engineers, January 11, 1904.

The Wisconsin Polytechnic Society withdrew from the Association in March, 1894.

The Western Society of Engineers withdrew in December, 1895.

The Engineers' Club of Kansas City disbanded at the close of 1896.

The Denver Society of Civil Engineers and the Association of Engineers of Virginia disbanded in 1898.

For the Engineers' Club of Cincinnati see footnote to Appendix F, Secretary's Annual Report for 1902, vol. xxx, No. 1, page 57, January, 1903.

Annual Report of the Chairman of the Board of Managers.

Boston, Mass., December 31, 1904.

To the Members of the Association of Engineering Societies.

Gentlemen:—In conformity with the Articles of Association, I have the honor to present the annual report of the transactions of the Board during the year 1904, together with the report of the Secretary for the same period.

From the latter it appears that the gain in membership of the Societies forming the Association has been larger during the past year than during any of the previous ten years, and also that there has been an increase in the number of pages in the Journal. About one-half of the increase in membership is due to the admission of the Toledo Society of Engineers in January.

It also appears from the Secretary's report that there has been a very large increase in the cost of publishing the Journal. This has been due to an increase of about 33 per cent. in the prices paid for printing, an increase of 18.2 per cent. in the number of pages in the Journal, and a large increase in the number of illustrations.

In consequence of this increased cost of publication it has been found necessary to increase the assessment, for 1904, from $2 to 2.50 per member, and I regret to say that notwithstanding this increase there has been a reduction in the assets of the Association. In considering the cost of the Journal to the members of the Association it must be remembered that the Societies obtaining advertisements for the Journal have received $823.50 for commissions on same, and that this sum, if equally divided among the total membership, would be equivalent to nearly $0.50 per member.

At the suggestion of the Secretary the question of codifying and revising the rules of the Board of Managers has been carefully considered, and it is expected that final action on this subject will be taken by the Board within a few weeks.

I very much regret to inform the members of the resignation of our Secretary, Mr. John C. Trautwine, Jr., which was received September 14th, to take effect on January 1, 1905. During his administration Mr. Trautwine has taken a very active interest in the welfare of the Association, and for his efficient management of the Journal and for his painstaking work as editor, the members of the Association are very much indebted. Those who have been associated with him have realized that much of the work which he has done has been done for love of the Association and from a personal desire to make it a success rather than for the monetary

consideration, which did not adequately compensate for the time which he has given to the work. Mr. Trautwine now feels that he cannot longer devote sufficient time to the work without seriously neglecting his own interests, and it does not seem fitting that he should be expected to continue to sacrifice these for the welfare of the Association. The selection of a new Secretary is now receiving the careful consideration of the Board, and Mr. Trautwine has very kindly consented to continue in charge of the publication of the JOURNAL until his successor is elected.

In closing, I desire to express the hope that during the coming year every member of the several Societies will join with the Board of Managers in forwarding the interests of the Association, either by the presentation of papers or by obtaining advertisements for the JOURNAL, so that we may make the year to come a prosperous one.

Respectfully,

DEXTER BRACKETT, *Chairman.*

Annual Report of the Secretary of the Board of Managers.

PHILADELPHIA, December 31, 1904.

Mr. Dexter Brackett, Chairman,

1 Ashburton Place, Boston, Mass.

DEAR SIR:—I have the honor to present the following report upon the operations of the Secretary's office during the year 1904, and upon the condition of the affairs of the Association at the present time.

These data are concisely stated in the following statistical appendices:

A. Statement of receipts and expenditures during 1904.

B. Expenses and earnings for 1904 ("Profit and Loss").

C. Balance sheet, December 31, 1904.

D. Detailed statement of gross cost of JOURNAL during 1904, by months.

E. Net cost of JOURNAL during 1904.

F. Statement of material in JOURNAL during 1904.

G. Comparison of the mail lists of the JOURNAL at the close of 1903 and of 1904.

H. Comparison of conditions, 1894 to 1904, inclusive.

J. Comparison of conditions, 1902, 1903, 1904.

Prior to 1904 the chief book of the Association was the cash book, and beyond this no attempt was made to conduct the accounts by double entry; but with the beginning of 1904 a double-entry system was introduced. This has rendered advisable certain changes in the statement of the accounts, as follows:

1. The appearance of the Association's stock of JOURNALS and Index, as assets.

2. The statement, in Appendix H, of net *earnings* from advertisements, instead of net *receipts*, as heretofore.

3. The inclusion, under Cost of Illustrations, of the printers' charges for paper, presswork and inserting; items which were formerly included with the printers' bills, leaving (under the former system) only the preparation of cuts and of lithographic stones, and paper and presswork on lithographic insets, to be charged to Illustrations.

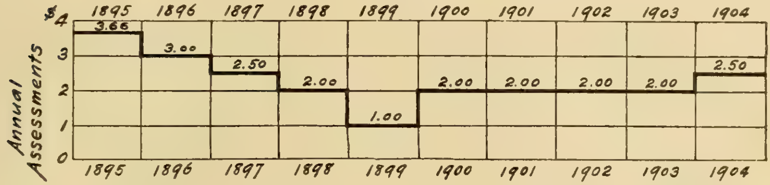
4. The omission of the cost of the December JOURNAL from the statement of Liabilities.

The notable feature of the year's business has been the effect of the advance of one-third in the printers' rates, which went into effect with the issue of the JOURNAL for September, 1903.

As a result of this, and as stated in my report for 1903, our cash balance and our net assets, at the close of 1903, were slightly less than at the close of 1902. The annual assessment of $2 per member, established in 1898, had been maintained.

But the increased rates for printers' work, operative during the whole of 1904, have so far reduced the Association's available assets as to render it necessary to levy an assessment of $2.50 per member for the year, instead of $2. This was done by making the fourth assessment $1 per member, the three preceding quarterly assessments having been at the usual rate of 50 cents per member. The following diagram shows the rates of assessment

charged from 1895 to 1904 inclusive. It will be remembered that, during 1899, a special rebate of $1 per member was made from the rate of $2 charged in 1898, leaving the net rate, for 1899, only $1 per member.



RATE OF ANNUAL ASSESSMENTS, 1895-1904.

Appendix J shows an increase of over 49 per cent. in the gross cost of the JOURNAL and of nearly 56 per cent. in its net cost, as compared with 1903, and a virtual decrease (see footnote, Appendix J) of 42 per cent. in net assets, notwithstanding the increase in assessment, above noted, without which the net assets, at the close of 1904, would have been reduced, virtually, to $557.81, a decrease of $1918.73, or 77.5 per cent.

The total membership of the Societies has increased by 155, or by nearly 9 per cent., nearly half of which is due to the admission of the Toledo Society of Engineers, with 71 members, in January, 1904.

The St. Louis, Cleveland, Boston and Buffalo Societies have continued procuring advertisements for the Association JOURNAL, and our two youngest members, the Louisiana and Toledo Societies, have made beginnings in this direction. As a result, the earnings for 1904, from advertisements procured by the Societies, have reached $915, out of which the Societies retain 90 per cent., or $823.50.

The exchange of advertisements, between the JOURNAL and a number of the best engineering periodicals, has been continued.

During the year 1904, forty-nine papers were published in the Association JOURNAL. See Tables of Contents, printed in the issues for June and December, 1904.

Respectfully submitted,

JOHN C. TRAUTWINE, JR., *Secretary.*

APPENDIX A.

Statement of Receipts and Expenditures during 1904.

CASH, 1904.

Dr.

To Cash Balance, January 1, 1904	$1,495.61	
" Engineers' Club of St. Louis	466.25	
" Civil Engineers' Club of Cleveland	499.45	
" Boston Society of Civil Engineers	1,526.36	
" Engineers' Club of Minneapolis	143.00	
" Civil Engineers' Society of St. Paul	64.50	
" Montana Society of Engineers	166.75	
" Technical Society of the Pacific Coast	254.75	
" Detroit Engineering Society	195.42	
" Engineers' Society of Western New York	196.10	
" Louisiana Engineering Society	101.00	
" Toledo Society of Engineers	166.60	
" Subscriptions (net)	531.15	
" Sales of Journal "	135.56	
" " " Descriptive Index "	20.00	
" " " Reprints	118.17	
" " " Sundries	12.70	
" Advertisements*	278.00	
" Interest on Deposits	40.17	
" Postage stamps sold	1.22	
		$6,412.76

Cr.

By Patterson & White Co. (Printers)		$4,074.10	
" Illustrations		1,082.23	
" Secretary's salary		600.00	
" Civil Engineers' Club of Cleveland		61.20	
" Advertising agents (commissions, etc.)		26.00	
" Traveling expenses		3.25	
" Bookbinding		4.10	
" Telegraph, telephone and messenger service		9.88	
" Express charges		4.15	
" Stationery		34.11	
" Postage†		47.81	
" Subscriptions refunded		6.00	
" Journals bought		2.00	
			$5,954.83
" Cash Balance, December 31, 1904:			
Provident Life and Trust Co.	$439.91		
Checks on hand	15.50		
Cash on hand	2.52		
			457.93
			$6,412.76

* Exclusive of receipts from advertisements obtained by the Societies in the Association.

† Exclusive of postage paid by the printers for mailing Journal.

APPENDIX B.

Earnings and Expenses for 1904.

("Profit and Loss.")

EXPENSES.

Printing and binding	$3,140.82	
Illustrations (*a*)	1,701.18	
Mailing (*b*)	279.14	
Secretary's salary	600.00	
Advertising expenses (*c*)	29.80	
Stationery	106.21	
Postage (*d*)	106.54	
Telegrams, etc.	9.88	
Express charges	6.50	
Sundry expenses	21.50	
Subscriptions for 1901 and earlier years, charged off as uncollectible	210.00	
Commission on advertisements received through the Societies	823.50	
Commission on sales of Journal	28.35	
" " " " Descriptive Index	5.00	
" " subscriptions	27.22	
Sales of reprints (*e*)	12.13	
		$7,107.77

EARNINGS.

Advertisements received through the Societies	$915.00	
" secured by the Association	120.08	
Sales of Journal	154.76	
" " Descriptive Index	27.25	
" " sundries	4.15	
" " exchanges	16.60	
Assessments	4,300.50	
Subscriptions	732.37	
Interest	40.17	
		6310.88
Excess of expenses over earnings		$796.89

NOTES.

(*a*) The amount ($1,701.18), charged for illustrations, includes the printers' charges ($688.35), for paper, presswork and inserting, not included in this item in previous reports.

(*b*) The amount ($279.14), charged for mailing, includes postage on the Journal.

(*c*) The item of advertising expenses covers expenditures for advertising the Association and its Journal.

(*d*) The amount ($106.54), charged for postage, is exclusive of postage on the mailing of the Journal.

(*e*) The printers' rates for reprints, like those on the Journal proper, have been sharply advanced, so much so that the management has hesitated to make a corresponding advance in the prices charged, which formerly brought a profit to the Association. Owing to this, the sale of reprints, during 1904, shows a slight loss.

APPENDIX C.

Balance Sheet, December 31, 1904.

ASSETS.

Cash		$457.93
Receivable from		
Societies:		
Engineers' Club of St. Louis	$257.25	
Civil Engineers' Club of Cleveland	216.30	
Boston Society of Civil Engineers	94.45	
Engineers' Club of Minneapolis	100.00	
Montana Society of Engineers	158.00	
Technical Society of the Pacific Coast	200.15	
Detroit Engineering Society	200.00	
Engineers' Society of Western New York	70.00	
Louisiana Engineering Society	114.50	
Toledo Society of Engineers	4.35	
		1,415.00
Subscribers:		
Subscriptions due:		
Entered or renewed in 1904	$183.00	
" " " " 1903	27.00	
" " " " 1902 (*a*)	3.00	
		213.00
Purchasers of Journal		7.90
" " reprints (*b*)		15.75
" " Descriptive Index		5.00
" " sundries		31.25
Advertisers (*b*)		220.66
Stock of Journal (*c*)—43,000 copies at 1 cent		430.00
Stock of Descriptive Index (*c*)—		
Vol. 1, 24 copies, at $5.00	$120.00	
" 2, 1 " " 5.00	5.00	
" 3, 9 " " 7.50	67.50	
		192.50
		$2,988.99

LIABILITIES.

Patterson & White Co. (Printers):			
For October Journal	$317.54		
" November " (*d*)	317.40		
		$634.94	
" reprints, stationery, etc.		53.40	
			688.34
Net assets, December 31, 1904			$2,300.65

NOTES.

(*a*) Subscriptions for 1901 and earlier years, amounting to $210.00, have been charged off to "Earnings and Expenses" as probably uncollectible. Records of the balances due are kept, however, and efforts will be made to collect them.

(*b*) The amounts entered as receivable from sales of reprints and from advertisements are exclusive of such amounts due from the Societies, which are included in the amounts entered as "Receivable from the Societies."

(*c*) The Association's stocks of its own JOURNAL and of the Descriptive Index to Engineering Literature have not heretofore been included in statements of assets. The stock of the JOURNAL is estimated at about 43,000 copies, and, owing to the uncertainty of their sale, they are taken at the nominal figure of 1 cent each—one-thirtieth of the published price, about one-twentieth of the gross cost in 1904, and one-eighteenth of the net cost. The Descriptive Index, on the contrary, sells steadily, and there is but a small stock left. They are accordingly taken at their advertised prices, which they readily bring.

(*d*) In previous reports, the cost of the December JOURNAL has been included as a liability; but, as it is not issued or billed until January of the following year, it cannot properly be entered on the books for the current year. It is therefore omitted from this report. The printers' bill for the JOURNAL for December, 1904, was $241.34.

LIABILITIES AND ASSETS ACCOUNT.

Dr.

1904		
July 13th, error in balance January 1, 1904 (bill paid during 1903)	$1.50	
December 31st, reduction in stock of Descriptive Index during 1904	20.00	
December 31st, expenses during 1904 (Appendix B)	7,107.77	
" " balance	2,300.65	
		$9,429.92

Cr.

1904		
January 1st, balance (net assets)	$2,476.54	
" " stock of JOURNAL (estimated)	400.00	
" " " " Descriptive Index	212.50	
December 31st, increase in stock of JOURNAL during 1904 (estimated)	30.00	
December 31st, earnings during 1904 (Appendix B)	6,310.88	
		$9,429.92
1905		
January 1st, balance (net assets)		$2,300.65

APPENDIX D.

Detailed Statement of Gross Cost of Journal during 1904, by Months.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Composition.	Paper, Presswork, Binding.	Wrapping, etc.	Postage.	Printer, Sum of 1, 2, 3 and 4.	Illustrations.*	Cost of Manufact'e Sum of 1, 2, 6.	Wrappers.	Sec'y's Salary.	Sundries.†	Total. Sum of 5, 6, 8, 9, 10.	No. of Pages.‡	Total Cost per Page.‡	Copies Printed.
January	$362 81	$276 23	$8 05	$23 36	$670 45	$187 06	$826 10	$4 75	$50 00	$21 17	$933 43	194	$4 81	2,350
February........	48 17	89 50	6 51	8 69	152 87	160 40	298 07	4 75	50 00	21 17	389 19	58	6 71	2,250
March	104 34	138 89	6 42	16 24	265 89	292 84	536 07	4 75	50 00	21 17	634 65	94	6 75	2,350
April..............	99 62	143 59	5 64	13 57	262 42	61 45	304 66	4 75	50 00	21 18	399 80	96	4 16	2,350
May................	128 66	160 04	6 39	16 15	311 24	109 93	398 63	4 75	50 00	21 18	497 10	110	4 52	2,350
June................	153 05	146 47	5 39	17 12	322 03	294 50	594 02	4 75	50 00	21 18	692 46	100	6 92	2,350
July	32 26	70 14	5 77	7 91	116 08	83 30	185 70	4 75	50 00	21 18	275 31	48	5 74	2,350
August...........	77 61	104 17	4 70	11 41	197 89	115 55	297 33	4 75	50 00	21 18	389 37	72	5 41	2,350
September......	227 81	245 93	5 85	21 26	500 85	115 72	589 46	4 75	50 00	21 18	692 50	162	4 27	2,350
October	118 85	160 80	4 85	13 04	297 54	20 95	300 60	4 75	50 00	21 18	394 42	104	3 79	2,500
November......	88 28	138 30	5 47	13 10	245 15	171 14	397 72	4 75	50 00	21 18	492 22	88	5 59	2,500
December	84 71	121 90	6 25	13 23	226 09	70 97	277 58	4 75	50 00	21 18	372 99	74	5 04	2,500
Totals and averages...	$1,526 17	$1,795 96	$71 29	$175 08	$3,568 50	$1,683 81	$5,005 94	$57 00	$600 00	$254 13	$6,163 44	1,200	$5 14	28,550§

* The figures in column 6 (Illustrations) include preparation of cuts and lithographic stones, paper, presswork and inserting.

† The figures in column 10 (Sundries) include all expenditures of the Association (such as stationery, postage, circulars, etc.) chargeable to the Journal and not embraced in any other column. They do not include the cost of preparing reprints of papers, commissions or other expenses connected with advertisements, or commissions on subscriptions, sales, etc.

‡ The figures in columns 12 (No. of Pages) and 13 (Cost per Page) include 4 cover pages in each number, and 16 pages in indexes to Vols. XXX and XXXI.

§ Gross cost per 100 copies, 1904, $21.59; 1903, $15.20. Increase, 1904, $6.39 = 42.0 per cent.

APPENDIX E.

NET COST OF JOURNAL, 1904.

Gross cost, as per Appendix D			$6,163.44
Add cost of reprints		$202.26	
Less sales of reprints		190.13	
			12.13
			$6,185.57
Deduct earnings, as per Appendix B:			
From subscriptions	$732.37		
Less commissions	27.22		
		$705.15	
From sales of JOURNALS	$154.76		
Less commissions	28.35		
		126.41	
From sales of Descriptive Index	$27.25		
Less commissions	5.00		
		22.25	
From sales of exchanges		16.60	
" " " sundries		4.15	
From Association advertisements		120.08	
From Society advertisements	$915.00		
Less commissions	823.50		
		91.50	
From interest on deposits		40.17	
			1,126.31
Net cost of JOURNAL, 1904:			
January to December inclusive			$5.059.26
Net cost per 100 copies, 1904			$17.72
" " " " " 1903			11.93
Increase, 1904, 48.5 per cent			$5.79

APPENDIX F.

STATEMENT OF MATERIAL IN JOURNAL DURING 1904, BY PAGES.

	Papers.	Proceedings.	Chairman's Report, etc.	Advertisements.	Indexes to Vols.	List of Members.	Totals.	Cuts.	Plates and Full-Page Cuts.
January	28	20	36	18	. .	88	190	5	8
February	30	4	. .	20	. .	. .	54	7	7
March	53	16	. .	20	. .	. .	89	21	10
April	63	7	. .	20	. .	. .	90	28	0
May	79	5	. .	20	. .	. .	104	16	4
June	63	4	. .	20	8	. .	95	13	28
July	23	0	. .	20	. .	. .	43	8	7
August	48	0	. .	20	. .	. .	68	5	7
September	125	12	. .	20	. .	. .	157	47	8
October	71	8	. .	20	. .	. .	99	2	0
November	60	3	. .	20	. .	. .	83	25	4
December	38	4	. .	18	9	. .	69	1	3
Totals	681	83	36	236	17	88	1141	178	84
Covers							48		
Total							1189		

APPENDIX G.

Comparison of the mailing lists of the JOURNAL, at the close of 1903 and 1904, respectively:

	1903.	1904.	Increase.	Decrease.
Engineers' Club of St. Louis	225	209	..	16
Civil Engineers' Club of Cleveland	216	216	..	..
Boston Society of Civil Engineers	520	595	75	..
Engineers' Club of Minneapolis	86	98	12	..
Civil Engineers' Society of St. Paul	21	21	..	..
Montana Society of Engineers	109	102	..	7
Technical Society of the Pacific Coast	154	171	17	..
Detroit Engineering Society	122	139	17	..
Engineers' Society of Western New York	68	51	..	17
Louisiana Engineering Society	67	70	3	..
Toledo Society of Engineers	...	71	71	..
In the Societies composing the Association	1588	1743	195	40
Net Increase	**155**			
Extra copies to Societies	41	56	15	..
Advertisers	34	31	..	3
Exchanges	131	141	10	..
Subscribers	222	232	10	..
Complimentary copies	0	1	1	..
	2016	2204	231	43

Besides this, many copies have been sold and specimen pages sent out, and authors of papers have each received five copies of the JOURNAL containing them. In all, 2350 copies were printed of January and March-September, inclusive, 2250 of February, and 2500 of October-December, inclusive.

APPENDIX H.

Comparison of Conditions, 1894 to 1904, Inclusive.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
							Pages of Papers.		Gross Cost of Journal.*					Illustrations.			
Year.	Number of Societies in Association, Dec. 31.	Number of Names on Mail Lists of Societies, Dec. 31.	Subscribers, Dec. 31.	Exchanges, Dec. 31.	Net Earnings from Advertisements.	Total Number of Pages in Journal.	Total.	Per 1000 Members on Mail List.	Total.	Per Page.	Per Member.	Per Member per 1000 Pages.	Annual Assessment per Member.	Small Cuts.	Plates and Full-Page Cuts.	Cost. Appendix B.	Net Assets, Dec. 31. Appendix C.
1894	8	1174	176	110	$671 00	1290	653	556	$5774 59	$4 48	$4 92	$3 81	$3 00	86	54	$651 60	—$758 91‡
1895	11	1477	215	122	599 09	1482	792	536	5911 48	3 99	4 00	2 70	3 66	116	66	859 60	223 93
1896	9	1106	241	108	763 25	856	490	443	3928 42	4 59	3 55	4 15	3 00	62	56	771 39	1244 94
1897	10	1252	233	102	410 25	1016	638	510	3140 43	3 09	2 51	2 47	2 50	57	45	503 85	2562 04
1898	12	1370	246	114	465 58	1110	738	539	3462 08	3 12	2 53	2 28	2 00	166	42	729 38	2936 71
1899	11	1475	249	115	390 88	958	544	369	3233 44	3 38	2 19	2 29	2 00†	124	30	561 24	2442 70†
1900	11	1541	216	116	370 83	1130	666	432	4351 53	3 85	2 82	2 50	2 00	112	27	590 82	2162 67
1901	11	1597	224	115	244 10§	1074	646	405	4856 64	4 52	3 04	2 83	2 00	213	55	1160 90	2062 72
1902	11	1544	220	135	260 60	1030	610	395	3927 01	3 81	2 54	2 36	2 00	172	20	442 43	2601 19
1903	10	1588	222	131	108 80	1006	568	358	4133 24	4 11	2 60	2 58	2 00	78	63	773 47	2476 54
1904	11	1743	232	141	211 58	1189	681	391	6163 44	5 18	3 54	2 98	2 50	178	84	1701 18	2300 65

*The publication of the Descriptive Index of Current Technical Literature was discontinued at the end of 1895.

† During 1899, with an assessment of $2.00 per member, the Association made a rebate of $1.00 per member for the purpose of reducing surplus, making the actual charge only $1.00 per member, and reducing the assessment by about $1400.

‡ Deficit at close of 1894. Since then, each year has shown a surplus.

§ In Appendix F, for 1894–1901, as printed in the Journal for January, 1902, the gross receipts, $331.50, were given, by oversight, instead of the net receipts, $244.10.

APPENDIX J.

Comparison of Conditions, 1902, 1903, 1904.

	1	2	3	4	5	6				7				8
						Gross Cost of Journal.				Net Cost of Journal.				
						a	b	c	d	a	b	c	d	
December 31st.	Members on Mail List.	Total Pages in Journal.	Printers' Bills for Journal.	Cost of Illustrations.*	Cost of Manufacture.	Total.	Per Page.	Per Member.	Per Member per 1000 Pages.	Total.	Per Page.	Per Member.	Per Member per 1000 Pages.	Net Assets.
	App. H, Col. 2.	App. H, Col. 6.	App. D, Col. 5.	App. H.	App. D, Col. 7.	App. H, Col. 9.	App. H, Col. 10.	App. H, Col. 11.	App. H, Col. 12.	App. E.				App. G, Col. 17.
1902	1544	1030	$2637.13	$442.43	$2909.29	$3927.01	$3.81	$2.54	$2.36	$2588.58	$2.51	$1.68	$1.63	$2601.19
Increase	44	......	......	$331.04	$225.51	$206.23	$0.30	$0.06	$0.22	$657.00	$0.72	$0.36	$0.37	......
Decrease	......	24	$93.68	......	......	......	......	......	......	......	......	......	......	$124.65
Per Cent.	2.8	2.3	3.6	7.5	7.8	5.3	7.9	2.4	9.3	25.4	28.7	21.4	22.7	4.8
1903	1588	1006	$2543.45	$773.47	$3134.80	$4133.24	$4.11	$2.60	$2.58	$3245.58	$3.23	$2.04	$2.00	$2476.54†
Increase	155	183	$1770.40	$221.99	$1871.14	$2030.20	$1.03	$0.94	$0.40	$1813.68	$1.03	$0.86	$0.44	......
Decrease	......	......	......	......	......	......	......	......	......	......	......	......	......	$175.89†
Per Cent.	9.8	18.2	69.6	28.7	59.7	49.1	25.1	36.2	15.5	55.9	31.9	42.2	22.0	7.1†
1904	1743	1189	$4313.85	$995.46	$5005.94	$6163.44	$5.14	$3.54	$2.98	$5059.26	$4.26	$2.90	$2.44	$2300.65†

* Exclusive of printers' bills for paper and presswork on cuts, and inserting.

† The decrease in net assets, during 1904, is here made to appear much less than it is in fact, by the counting, as assets at close of 1904, of the Association's stock of Descriptive Index, $192.50, and of the Journal, estimated at $430.00, neither of which has hitherto been included, and by the omission of the cost ($241.34) of the December Journal from the statement of liabilities. Omitting the stocks of Journal and of Index from the assets, and including the cost of the December Journal with the liabilities, as heretofore, we should have: net assets, December 31, 1904, $1,436.81; decrease, $1,039.73. Per cent., 42.0.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

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THE SEWAGE DISPOSAL WORKS AT SARATOGA, N. Y.

BY F. A. BARBOUR, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Sanitary Section of the Society, January 4, 1905.*]

SARATOGA Springs has long been noted as a summer resort. The normal population of 12,000 is, by the advent of visitors, rapidly increased, during the summer season, to 30,000, and in the month of August to a maximum of 50,000 people. This so-called village, therefore, presents unusual conditions for consideration in the undertaking of any municipal improvement. Not only does the annual increase in population take place, but a greater and disproportionate demand for municipal conveniences results, making the provision for water supply and sewerage necessarily out of all proportion to the regular population. When, therefore, the problem of sewage disposal presented itself for solution, it was not the condition of a village of 12,000 people which must determine the design, but rather those of a city of 40,000.

The main portion of the village of Saratoga Springs rests on the southeastern slope of the extremity of an easterly spur of the Adirondacks, while the remaining portion of this village, separated by the head of the valley of Village Brook, lies along the southerly side of the valley and spreads out over the sandy plain which stretches southward.

The natural drainage of the area occupied by Saratoga Springs is directly into Village Brook, which, after following a very tortuous course for about three miles, discharges into Lonely Lake. This lake drains into Saratoga Lake, and this in turn through Fish Creek into the Hudson River.

* Manuscript received February 8, 1905.—Secretary, Ass'n of Eng. Socs.

The sewerage system was originally constructed on the "combined" plan. The main interceptor was a 36-inch single-ring brick conduit, laid through the valley of Village Brook, in great part well below the level of the stream bed. It ended near the Eureka Spring —about 5000 feet below the thickly settled limits of the village— and at this point the sewage was for some years discharged into the brook.

Complaints from those living below the outlet led to the appointment, in 1882, of a commission to consider other means of disposal, and somewhat later it was decided to extend the main sewer about five miles to Kayaderosseras Creek—a stream discharging into Saratoga Lake. The interceptor to the original outlet was 36 inches in diameter, but the extension was made only 24 inches in diameter. The capacity of the large conduit is 35 cubic feet per second, while that of the 24-inch sewer is only 7 cubic feet per second, the obvious intention in extending to the Kayaderosseras being that only the dry-weather flow should be carried to that point and that the excess during storms should overflow into the Village Brook at the end of the 36-inch sewer. A small settling tank was constructed at the head of the 24-inch sewer, either to insure the self-cleansing of the sewer or else to prevent trouble from floating matters in the Kayaderosseras.

Whatever the reason, the apparent result was a failure, and a nuisance—judging from court decisions—was created at both points, that at the Kayaderosseras from the regular discharge and that at the Village Brook from the storm overflow and the handling of the deposited solids at the time of their removal from the settling tank. Twenty-three suits for damages were filed against the village, nineteen of these being based on the results of the intermittent storm discharge into the Village Brook and the remainder on the effects of the dry-weather flow into the Kayaderosseras. The complaints alleged the existence of offensive odors, that cattle would not drink the water and that the meadow land was damaged by the stranding of suspended solids. Four cases were carried to the Court of Appeals, with results unfavorable to the defendant. The total damages paid by the village of Saratoga Springs exceeded $20,000.

It is interesting to note that, in the consideration of these cases, the court followed closely the axiom that a riparian owner has a right to the flow of the stream as "it is wont by nature" and a contributor of pollution is liable for damages regardless of other pollution or the diluting effects of the stream. Overflow into Village Brook could take place only when the sewage was diluted by sur-

face water so that the discharge exceeded 5,000,000 gallons per day, and only when the flow in the brook was increased to an extent where the resulting mixture of brook water and sewage was within the limits of the standard usually set for the prevention of a nuisance. These conditions were, however, of little value in the eyes of the law, and the plaintiff gained a standing from the fact that sewage had been discharged into the stream regardless of the subsequent dilution. The awards of the court covered damages to the plaintiffs for a limited time only, on the assumption that, after a certain date, Saratoga would install purification works.

In the early part of 1899 the pollution of Saratoga Lake was brought to the notice of the State authorities, and, after an investigation by the engineer of the Board of Health, it was concluded that a nuisance was being created by the villages of Saratoga Springs and Ballston Spa. On recommendation of the Board, Governor Roosevelt, acting under the provision of Chapter 661 of the Laws of 1893, ordered that these villages should, on or before April 1, 1900, put in disposal works for the sanitary treatment of the sewage. The time was subsequently extended for Saratoga. Ballston Spa has not yet constructed a disposal plant, but is preparing to do so.

In the summer of 1899 the writer was requested to make a preliminary investigation of the sewage disposal problem with a view to the adoption of intermittent filtration. Naturally one of the first considerations was the amount of water used daily. This latter was found to be so unreasonably high as to make the study of its reduction a necessary preliminary to the economical undertaking of sewage purification.

The water supply of Saratoga is taken from Loughberry Lake; the distribution is by direct pressure without storage,—two pumps, one of 5,000,000 gallons and one of 8,000,000 gallons daily capacity, being used. The distribution pipes are laid at very shallow depths, sometimes within 3½ feet of the surface. This feature suggested a large leakage from the mains and indicated the possibility of increased stoppage by freezing in case the consumption and velocities were reduced.

In 1899 metering of the supply was recommended, and in the following two years about 3000 meters were installed, at a cost of about $25,000. It is impossible to accurately estimate the daily consumption from the pump records because of the large percentage of slip and of water by-passed at times to the suction well. It may be said, however, that in 1899 the daily per capita use of water ranged from 225 gallons in the spring and fall to 400 gallons in

the winter months, and that in 1901 these figures were reduced to about 110 gallons per capita in the months of normal temperature and 130 gallons in the winter.

As a practical demonstration of the value of meters it is believed that no better instance exists than that above described. That the use of water was not still further reduced is probably due to large leakage from the mains and to the fact that the amount of water on which the minimum payment is based was made too high. The consumption has been lessened to the point where the 5,000,000-gallon pump can only be operated by turning high-pressure steam direct into the low-pressure cylinder and the 8,000,000-gallon pump used only at the time of maximum consumption and then at a speed one-third of its normal rate.

In connection with the study of water consumption it seemed advisable to ascertain if any large leaks in the mains had been developed by movements due to the shallow depth. The town was accordingly divided into four districts, and one district at a time cut out by shutting the required gates, and the reduction in the consumption between the hours of 12 midnight and 4 A.M. obtained by using the pumps—which were examined and newly packed—as a meter. This reduction in each case was practically proportionate to the length of pipe isolated, and it was concluded that if leakage from the mains existed it could only be remedied by a general replacing of the pipe system.

As has been already stated, the sewer was originally constructed on the "combined" system. Between the years 1898-1901, $40,000 was expended in the construction of new surface water drains, the old pipes being retained to serve as sanitary sewers.

In 1901 the local authorities felt that the necessary preliminaries of reducing the water consumption and diverting the surface water had been sufficiently accomplished to justify the construction of the disposal plant.

In undertaking this work, it was necessary to ascertain the amount of sewage to be treated, which, while indicated by the water supply, might differ considerably because of leakage. This factor was particularly important at Saratoga, in view of the seasonal changes due to varying population. A weir was accordingly constructed in the settling tank at the end of the 36-inch main sewer and readings taken by hook gauges, at fifteen-minute intervals, for twenty-four hours on several different dates.

The following table, which it is believed worth while to here insert, shows the results of these measurements:

TABLE SHOWING THE HOURLY RATE OF DISCHARGE OF MAIN SEWER ON THREE DAYS.

Time.	May 1-2. Rate in Thousand Gallons per 24 Hours.	May 1-2. Percentage of Daily Average.	June 25-26. Rate in Thousand Gallons per 24 Hours.	June 25-26. Percentage of Daily Average.	August 10-11. Rate in Thousand Gallons per 24 Hours.	August 10-11. Percentage of Daily Average.
7- 8 A. M...	2408	97.0	2319	93.2	2606	96.0
8- 9 " ..	2520	101.0	2638	106.0	3037	112.0
9-10 " ..	2740	110.0	2856	114.0	3140	116.0
10-11 " ..	2649	106.0	2928	118.0	3230	119.0
11-12 " ..	2902	116.5	2902	117.0	3265	120.0
12- 1 P. M...	2778	112.0	2682	108.0	3252	120.0
1- 2 " ..	2708	108.9	2580	103.0	3123	115.0
2- 3 " ..	2804	113.0	2591	104.0	3100	114.0
3- 4 " ..	2630	106.0	2590	104.0	3043	112.0
4- 5 " ..	2610	105.0	2659	107.0	2960	109.0
5- 6 " ..	2497	100.0	2734	110.0	2791	103.0
6- 7 " ..	2472	100.0	2682	109.0	2932	108.0
7- 8 " ..	2487	100.0	2643	106.0	3182	116.0
8- 9 " ..	2406	99.2	2640	104.0	3100	114.0
9-10 " ..	2441	98.5	2584	101.0	2931	107.0
10-11 " ..	2340	94.5	2512	99.0	2647	97.5
11-12 " ..	2299	92.5	2454	95.0	2494	91.0
12- 1 A. M...	2292	92.4	2364	90.0	2338	86.0
1- 2 " ..	2256	91.5	2243	95.0	2517	87.5
2- 3 " ..	2233	90.0	2061	90.0	2054	76.5
3- 4 " ..	2241	90.0	1983	83.0	1952	72.0
4- 5 " ..	2240	90.0	1995	79.0	1912	70.0
5- 6 " ..	2256	90.5	2002	80.0	1912	70.0
6- 7 " ..	2289	92.0	2137	80.0	2015	74.0
Average...	2482		2494		2724	

The discharge of the 36-inch main sewer, as given by these gaugings, included a large amount of water from the different springs, which, if a new main were constructed, would not have to be handled. In order to know the future sewage to be treated, it therefore became necessary to estimate the amount of these inflows, and, in doing this, measurements of the flow in the main sewer at frequent intervals of its length and of the flow in the contributory laterals were made. In this work a form of Pitot tube, specially devised, was found very convenient. It consisted merely of two brass tubes, with elbows at the bottom, one pointing up-stream and one at right angles—and glass gauges in their length—both tubes firmly attached to a collar, which could be moved up and down on a vertical standard and fastened at any elevation by a set screw. Each brass tube had a stop-cock just above the elbow, these stop-cocks being opened or closed by geared pinions through the movement of a double-faced rack. By placing the standard on the invert

of the sewer and lowering the collar until the mouth of the tube was at the proper level, then opening the stop-cocks and, after an interval, closing, the liquid would be caught in the two tubes. The apparatus could then be lifted up to read the difference of level in the two gauges, and the velocity of flow so ascertained. Where the depth of flow was very small, a partial vacuum could be created in the tubes by a rubber bulb, and the liquid made to rise so as to be readable in the glass gauges. The instrument was calibrated by comparing the discharge as measured by it with that given by the weir. It was found that the velocity as shown by the tube had to be multiplied by a coefficient of 0.67 in order to give correct results. It may be interesting to note that the velocity as given by floats in a 36-inch sewer flowing one-third full had also to be corrected by a coefficient of 0.75, in order to agree with the weir measurements. The Pitot tube, of course, was merely a rough adaptation to the work in hand, not accurate but sufficiently so for the gauging of ordinary sewers. From the information gathered by the gaugings, it was estimated that, if a new main sewer were constructed, the flow of sewage would range from 1,500,000 to 1,700,000 gallons per day—except during the summer months when it would increase to a maximum of 2,500,000 gallons—on which quantities the design of the disposal plant was based.

It was accordingly recommended that a new sewer be constructed through the valley, ranging in size from 15 to 24 inches in diameter; the changes in size being made as shown to be necessary by the inflow from the laterals measured by the Pitot tube. The new main was planned on a flatter gradient than the old interceptor, and reached the outskirts of the village at an elevation which almost made it possible to dispose of the sewage by gravity.

The material which could be so utilized was not, however, entirely suitable, and the choice lay between some form of high-rate plant, reached by gravity or a low-pumping lift to very desirable sands. Contact beds or streaming filters demand more constant and expert attention than slow sand filtration, and, it was believed, would be less capable of meeting the abnormal variation in the quantity and quality of the sewage to be met with in Saratoga. The material in the higher territory, as shown by numerous borings with a sand auger, included 8 inches of loam, 2 feet of subsoil, and, underneath this, sand averaging in "effective size" about 0.20 m.m. with a coefficient of uniformity about 2—satisfactory in all the qualities necessary for filtration. Some of the borings were sunk to a depth of 16 feet without reaching the limit of the sand or finding water. The location was, from the standpoint of seclusion and

topography, almost ideal, and it was concluded to pump the sewage and utilize this area. In sewage disposal work the most important element is the obtaining of suitable materials at a reasonable distance from habitation, and it is frequently better to lift the sewage than to attempt its purification under inadequate conditions.

With the present knowledge of the art, the adoption of high-rate methods is, in the opinion of the writer, not justifiable where suitable sand can be obtained, even though the utilization of the latter involves a moderate lift of the sewage. When power for electric pumping is economically available, the cost of raising the sewage is easily offset by the lower cost of maintenance and the greater safety in operation of the more conservative plant.

The problem at Saratoga is notable for the seasonal variation in the quantity of the sewage, for the extremely low temperature, which averages about 20° F. during the months of January and February, and because of the necessity for high-class maintenance of the plant, particularly during the summer season.

Filtration of sewage demands consideration from two standpoints—firstly, that of the surface maintenance, and secondly, of the interior operations, whereby through chemical and bacterial agencies purification is effected. The surface maintenance determines the cost of operation, decides whether a local nuisance will be created and makes for the practical success or failure of the plant.

The suspended solids is the factor which clogs the surface of the filters, and if this element of the sewage is so handled, either by preliminary treatment as to prevent its application to the filters, or by frequent removal from the surface of the filters, there is relatively little difficulty in purifying the matter in solution. From the standpoint of the municipality the problem is one of disposing of the solids at the least possible cost in a way which will not create a nuisance, rather than one of purifying the liquid portion of the sewage. By this it is not intended that the design and material of the filter is not important, but rather that, in taking up to-day the planning of any disposal works, the factor which will most give pause to the engineer is the method to be adopted for the treatment of the solid matter.

One of the great merits of slow intermittent sand filtration is that if good material, in sufficient depth, is found, an acceptable effluent will almost surely be turned out under any conditions if the surface is properly maintained. The opportunity to the sanitary engineer for good work in the future lies in the evolution of a scheme which will make possible the economical disposal of the solid matters.

Among the various methods which have been already developed for the disposal of the suspended solids, the septic process is perhaps best known. Its description is not here necessary. It has been studied experimentally and used practically—sometimes with success and sometimes with failure.

Originally exploited as the final solution of the sludge problem, it is now known that generally more or less solids gradually accumulate in the tanks—in some places so rapidly as to make necessary their removal at frequent intervals, in others only after a period of several years.

Trouble in handling the stale sludge and difficulty in purifying the septic effluent have been the usual grounds for disapproval of this method. Ability to liquefy all the suspended matter is not, however, necessary for its justification. If by its use the surface of the filter during periods of low temperature can be kept clean, and if such a portion of the solids can be dissolved as to effectively reduce the cost of maintaining the plant, then in many cases the septic process is justified.

It is not necessary to create a nuisance, and if the effluent is properly treated there will be no difficulty in effecting purification. It has been a pronounced success in the personal experience of the writer, but just why, as compared with other places where a partial failure has resulted, is a difficult question to answer. The factors essential to success have not yet been determined, and will probably only be evolved by a long process of elimination in experience.

In the belief that by its use the abnormal variation in the amount of sewage would be somewhat equalized; that the solids could be withheld from the filters in the summer when the surface appearance is particularly important, and in winter during the period of low temperature; that a large portion of the suspended matter would be liquefied and the cost of maintenance thus reduced, the septic process was adopted at Saratoga.

The plant as proposed, therefore, included the construction of a new main sewer, the building of a small pump well and pumping station, the lifting of the sewage 15 feet by centrifugal pumps driven by electric motors, the laying of a force main 9000 feet in length, the building of septic tanks of 1,000,000 gallons capacity and the construction of 18 acres of sand filters.

There is nothing in the design or construction of the main sewer worthy of mention.

The pumping plant comprises a well of 16,000 gallons capacity, a small station built directly over the well, three 6-inch centrifugal pumps placed in the well so as to be submerged by the sewage, three

20 horse power electric motors directly connected by vertical shafts with the pumps and automatic starting and stopping apparatus, which, through the action of floats, make and break the electric circuit.

Septic tanks are preferably located at the disposal plant, and this arrangement, where the sewage has to be lifted, makes continuous pumping desirable. This is, moreover, dictated by economy in the reduced storage required at the pumping station and in the lessened diameter of force main.

Storage reservoirs for the night flow have in many cases been constructed in order to avoid night attendance. Limiting the pump run in this way to a few hours increases the necessary size of force main, but has certain advantages in the efficiency of the distribution of the sewage on the filters. This latter factor may, however, be nullified by automatic dosing.

The greatest economy from the standpoint of pipe friction is obtained by continuous pumping at a uniform rate throughout the twenty-four hours. This, however, requires an equalizing reservoir larger than it is economical to attempt, and the obvious solution is the adoption of a rate of pumping equal to the inflow of the gravity sewers. Such an arrangement can only be effected by variable speed of the pumps or the division of the pumping capacity into such a number of units that the work done at any time may be approximately adjusted to the load line as represented by the inflow.

Continuous pumping, in order to avoid night attendance, naturally suggests automatic starting and stopping apparatus, and this, in turn, the use of electric motors. Variable speed can be automatically obtained with direct current, but not with alternating current motors, and the use of the latter type, therefore, requires a reasonable division of the total pumping capacity into units, one or more of which will automatically come into operation as the inflow makes necessary. This is what was done at Saratoga, where three pumps were installed, each of 1000 gallons per minute capacity, when pumping against the head developed at the time all three are in operation. Two pumps are intended to take care of the maximum inflow at any time, the third being in reserve.

The pump well, situated on East Avenue, is constructed of concrete mixed 1 part cement, 3 parts sand and 5 parts crushed stone. It is 24.5 feet by 12 feet in size, and the bottom of the well is 10 feet below the invert of the main sewer. The sewage delivered by the interceptor passes through a screen and falls into a narrow chamber, from which it flows into one or more of the three pump pits

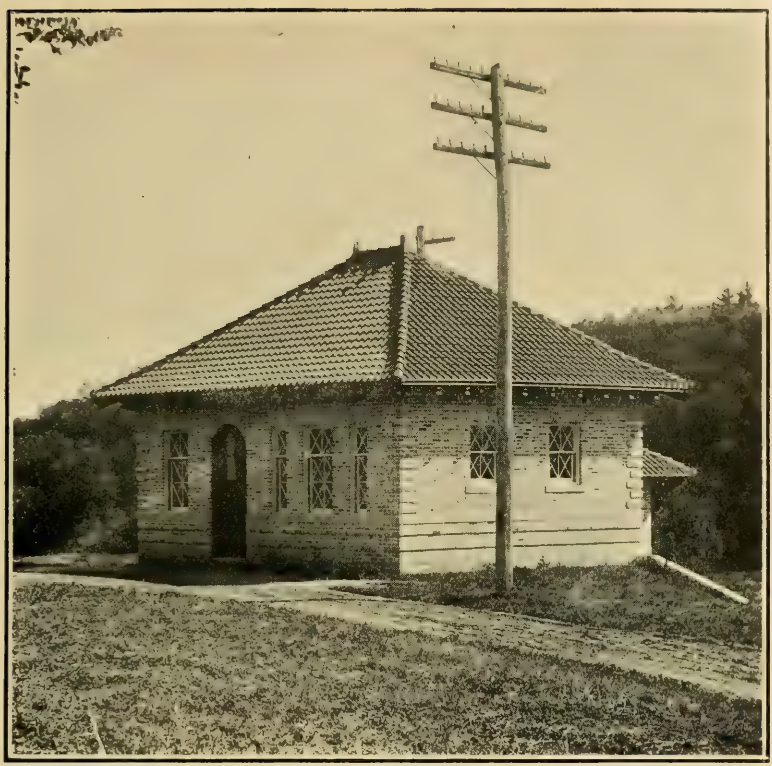
into which the well is divided, and any one of which may be shut off by closing a gate.

The screen is a counterbalanced cage, which is raised and lowered by a chain and sprocket wheel actuating a worm gear. The cage when full is lifted several feet above the ground floor, and the front drops back so as to permit the raking of the screenings directly into a wheelbarrow. A toothed comb lifts as the screen is raised and serves to temporarily prevent large solids reaching the pump. The screen bars are circular, ¾ inch in diameter and spaced 1¾ inches on centers. This was found to be not close enough for the operation of 6-inch centrifugal pumps of the usual type, and a screen of closer mesh was subsequently placed inside the cage. Pumps with larger clearance between the impeller casing and volute will take larger solids, but the efficiency is lower than that of the usual type. From more recent work it has been found that square are better than round bars for fine screens, and a cage of ⅝-inch bars, spaced 1¼ inches on centers, is about right for small pumps. Experience has also proved that spur gearing, with a ratchet to hold the cage at any desired level, is better than worm gearing for the hoist.

The pumping station is a small building, 20 by 25 feet inside measurements, with a rear projection, 8 by 10 feet in size, for the working of the screen hoist. The building is placed directly over the storage well, but there is no connection between the motor room and the well, entrance to the latter being obtained only through the screen room.

The station is constructed of Scotch fire-brick, with roof of red Ludowici tile, and is in no way a detriment to surrounding property or suggestive of the reason for its existence.

A 6-inch centrifugal pump is placed in each pump pit—supported by I-beams at an elevation about 30 inches above the floor of the well. Each pump is directly connected by vertical shafting, which is guided by two sets of I-beams, with the motor in the room above. A slip coupling is placed in each shaft just below the floor, the weight of the motor and its shaft being carried by the motor bearing and that of the pump shaft and the thrust of impeller by a thrust bearing set on the higher pair of I-beams. The use of the slip coupling is apparently essential, as it is difficult to so otherwise adjust the motor and thrust bearing that each will do its share of the work. It also permits the close adjustment of the impeller to bottom of pump casing, necessary to prevent clogging of the pump by small rags winding around the shaft. The thrust bearing is important in the design of vertical pumping connections, and one



Pumping Station.

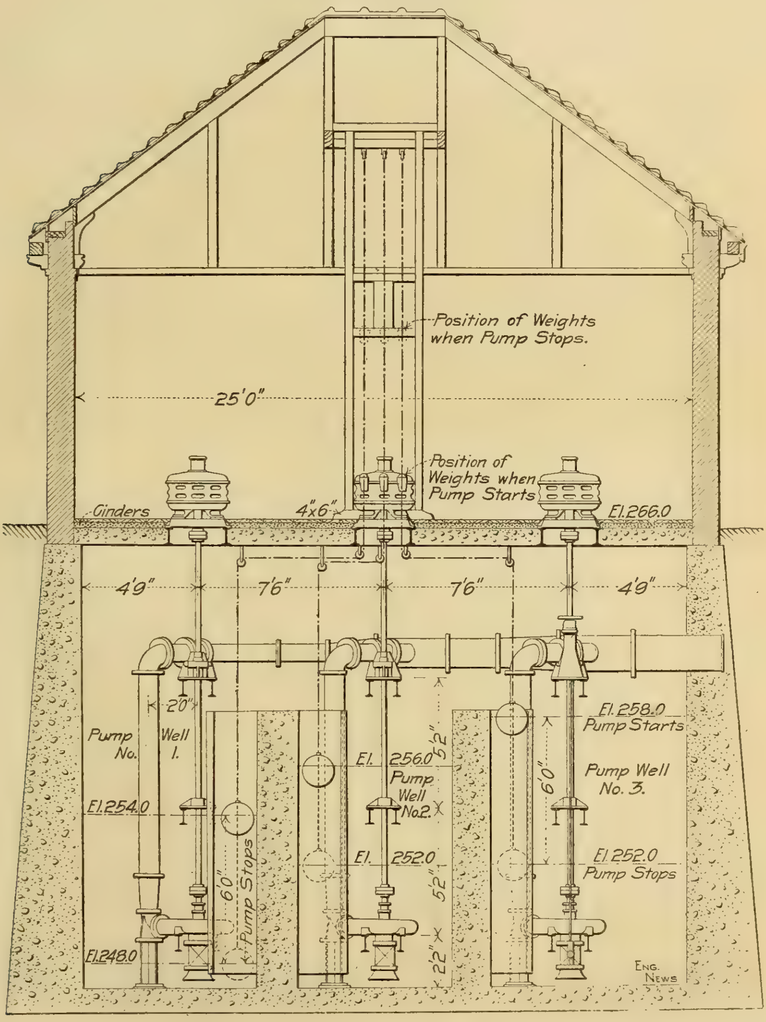
Interior View of Pumping Station.

SEPTIC TANK, SHOWING PLACING OF FLOOR.

SEPTIC TANK, SHOWING CONCRETE PIERS.

of the best types is that used in vertical motors in which the oil is continuously and automatically circulated by centrifugal force.

With an alternating current of a given frequency the speed of the motor can be regulated only within the choice of the number of



SECTION THROUGH SEWAGE PUMPING STATION, SHOWING ELECTRICALLY-DRIVEN CENTRIFUGAL PUMPS.*

poles. For close adaptation of the discharge of the pumps it is, therefore, necessary to vary the diameter of impeller and the resulting circumferential velocity. The slip of the motor must be taken into account and allowance made for the fact that in many cases

* Cut loaned by *Engineering News*.

generators are not run up to speed. The obtaining of the desired number of revolutions is important because a small reduction in the speed of centrifugal pumps, operating against a certain head, makes a relatively large reduction in the discharge.

The motors at Saratoga are vertical six-pole 20 horse-power induction motors with primary stator, using a three-phase current of forty cycles frequency. The power is obtained from the Hudson River Power Company, and is developed by a dam on the Hudson River at Spier's Falls. The current is delivered at a primary pressure of 2300 volts and stepped down to 220 volts by transformers placed on the outside of back wall of pumping station.

The nominal speed is 800 revolutions per minute, but the actual speed averages from 765 to 785 revolutions. Each pump has an 8-inch suction and 8-inch discharge pipe, a check and straightway valve being placed in each branch discharge. A valve was also placed in the short length of suction pipe below each pump, with the idea that when the inflow of sewage was less than the capacity of one pump the suction might be throttled. It is claimed that a centrifugal pump so throttled, in view of decreased force-main friction, will operate with greater efficiency than when running with full capacity. This has, however, not yet been tried at Saratoga.

In the corner of each pump pit a 15-inch copper ball is floated in a galvanized sheet-iron pipe. From the floats, chains, guided by pulleys, lead to automatic switches in the motor room above. The floats are counterweighted, and as they rise the counterweights pull down a lever to a horizontal position, from which a spring quickly completes the movement of the switch and starts the motor. As the sewage is lowered, a reverse action of the float and switch takes place, and, at a certain level of the sewage in the well, the motor is stopped. The floats are so arranged that No. 1 motor starts when the sewage reaches elevation 254, No. 2 at elevation 256 and No. 3, which is intended to be in reserve, at elevation 258. In shutting down, the motor, which starts last, stops first. In this way the pumping capacity, at any time in use, is as nearly adapted to the inflow as is practically possible with this type of plant. The units are interchangeable in their operation, and the scheme is, in the opinion of the writer, better than the adoption of pumping units of different capacities.

The automatic starting and stopping apparatus is entirely satisfactory in its operation—although the same danger exists in this as in all automatic apparatus, that it will be altogether neglected. There are certain parts of the plant which require more or less attention at times, among these being the switches which,

although submerged in oil, sometimes spark and burn so as to make an imperfect contact. In this way the circuit in two phases and not in the third may be completed, thus burning out the motors. This possibility can be avoided by the use of time-limit relays which, on the motor failing to start or on the pump becoming plugged by solid matters, automatically throw out a switch and shut off the current. These relays were installed at Saratoga after the danger existing without them had been learned by experience.

A test of the pumps showed a discharge of about 1575 gallons per minute for each pump running alone against a total head of 27.75 feet, with 775 revolutions per minute, and a discharge of 1180 gallons per minute for each pump when two pumps were running against a total head of 37.75 feet, and with a speed of 784 revolutions per minute. The average combined efficiency of pumps and motors is about 35 per cent. The pumping plant was installed by R. D. Wood & Co., the total cost being $5400. The building cost $2000 and the pump well about $2000.

The force main is 16 inches in diameter and 8835 feet long. It is laid level or with an ascending grade to a point about 4400 feet from the station, where a 4-inch air vent rising above the hydraulic gradient is placed. From this point it drops to a water course, where there is a blow-off, and then rises continuously to the septic tanks. It can be drained either to the pumping station or the blow-off. Heavy cuttings were opened in railroad fashion to a depth 4.5 feet above the top of the pipe. Bottom of cuttings and top of embankment are 6 feet in width.

The septic tanks have a total capacity of 1,000,000 gallons, divided into four units, each 91.5 feet long by 51.5 feet wide. High water is at elevation 272. The depth of sewage at inlet end is 7.75 feet and at outlet end 8.25 feet.

The entire structure is built of Portland cement concrete. The outside walls are 2 feet thick at the springing line of arches, vertical on the inside and with a batter of about $1\frac{1}{3}$ inches per foot on the outside. The division walls are 2 feet thick at the springing line and 3 feet thick at the level of the underside of floor. The piers are 18 inches square, the head being enlarged to 22 inches and the footing to 30 inches.

The roof is of elliptical groined arch construction, the span being 11 feet 6 inches and the rise 2 feet 6 inches. The thickness at crown is 6 inches and the plane of extrados is depressed 9 inches over the piers. This depression is drained by a 2-inch pipe through the roof into the tanks.

The floor is of inverted spherical groined arch construction, 6 inches thick at the center and 12 inches thick at the piers.

The force main ends in a chamber, from which a pipe leads across the inlet ends of the tanks. This pipe is carried by a concrete bracket reinforced by old railroad iron. Inlet chambers permit the shutting off of one or more tanks as desired. A by-pass pipe leads from the chamber at end of force main around the tanks, so that raw sewage can be applied directly to the beds. Inside of the tanks the inlet pipe is split and carried across the end of tank on a concrete bracket, four openings being provided for the discharge of the sewage at an elevation 3.5 feet below the high-water line.

The septic effluent escapes from the tanks through two horizontal rows of 2-inch pipe—ninety-six in all, set at an elevation about $3\frac{1}{2}$ feet below high-water line—into a narrow chamber extending the entire width of tank, from which it flows over a weir into the outlet chambers and thence to beds.

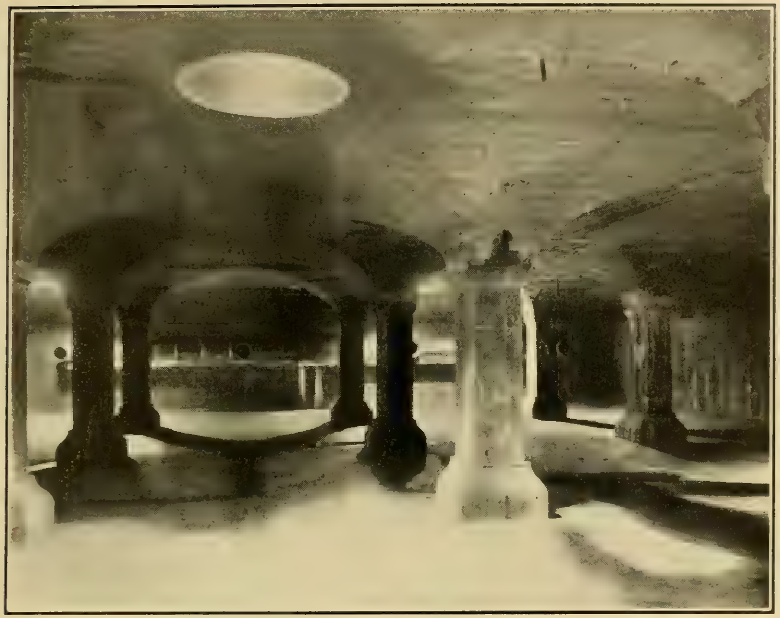
At the junction of the narrow transverse chambers a weir gate is placed, through which the effluent can be turned into the adjacent tank for storage in case it is the desire to apply the liquid to the beds during only the day hours in time of extremely low temperature. Opportunity to measure the quantity passing through each tank is afforded by the outlet weir and to thus properly regulate the flow by the inlet gate.

A 24-inch sludge gate permits the emptying of the sludge onto the sludge beds located directly in front of the tanks, and 12-inch gates at a higher elevation make it possible to draw off the clear liquid between the scum and deposit and apply it to any bed previous to the discharge of the sludge. All gate stems are carried through the roof in special nuts which contain the screw, in this way protecting the working surfaces from corrosion by the sewage. Six openings, 3 feet in diameter, are placed in the roof of each tank.

The walls were first constructed and the floor afterward laid by the usual method of placing the alternate quarter groins with wooden templates on the diagonals and then filling in between the concrete already laid. The side forms were built of 2 x 4 vertical studding spaced 18 inches on centers and 1-inch boarding, in sections 16 feet long.

Centers for the roof were provided for two tanks and used twice. The ribs were separately erected each time, no attempt being made to move the centers in sections.

All concrete was mixed by hand, two mixing-boards being kept in operation—thus making the work of placing practically continuous. The sand and cement were mixed dry, then water added, the



Septic Tank, Looking Toward Inlet End.

Septic Tanks, Looking Toward Outlet End.

Filter Beds, Looking South from Septic Tanks.

mortar well mixed, and then the stone dumped into the mixing-boards from wheelbarrows and the concrete turned over twice. A wet mixture was insisted upon, and the resulting surfaces turned out smooth and vitrified in appearance. Relatively little tamping was done.

The price of $2.50 per cubic yard paid for the concrete did not include the cost of the crushed stone, which was furnished by the local authorities, or the cement, for which the contractor was paid separately by the barrel.

The stone furnished was larger and more uniform in size of particle than was desirable and the percentage of voids greater than usual. A mixture of 1 part cement, 2½ or 3 parts sand and 5 parts stone, depending on the percentage of voids in sand and stone, was used. The only difference in roof and walls was a more careful selection of stone of smaller size for the roof. In this part of the work an endeavor was made to limit the stone to 1½ inches in diameter; in the sides and floors stone up to 2½ inches was used. The cement used per yard of concrete slightly exceeded 1.25 barrels —an amount higher than should have been the case.

The forms and centering were not handled in the most economical way by the contractor, from whose pay sheets it appears that this part of the work cost over $1.50 per cubic yard. This includes all form work for chambers, outlets, piers, brackets, roof, walls and floor—much of which was complicated and for thin work—and, while unquestionably this cost is higher than necessary, it is to be remembered that the use of concrete throughout in such structures involves a high cost for forms.

The cost of mixing and placing concrete was about 85 cents per cubic yard, and the total cost, figuring stone at $1.25 per cubic yard, amounted to about $7 per cubic yard.

The effluent of the septic process is devoid of oxygen, and before attempting its purification aëration, either incidental or by particular arrangement, should be effected. At Saratoga the effluent is passed over an aërator of perforated sheet-iron plates, hung in three layers around a central riser pipe. The liquid flows from the septic tanks in a 16-inch cast-iron pipe, from which by a T branch it rises through the central pipe of aërator and flows over the plates in a thin sheet.

The aërator is set in a circular well of concrete adjoining the dosing tank. By opening a gate at the end of the 16-inch pipe, the liquid can be admitted directly to the dosing tank without aëration.

The following results of the dissolved oxygen test may be interesting:

	Per Cent. of Saturation.
Sewage entering tanks	4.3
Effluent before aëration	0.0
Effluent immediately after aëration	70.4
Effluent as applied to filters	40.4

These figures indicate the avidity of the liquid for oxygen, and while it may be difficult to demonstrate the actual value of this special aëration, it is reasonable to believe that otherwise the available oxygen in the beds would be used up preliminary to the commencement of nitrification. At all events, there has been no difficulty at Saratoga in effecting nitrification of the septic effluent.

The effluent after passing over the aërator falls into the inclosing circular concrete chamber and then flows into an adjacent dosing tank. The combined capacity of the aërator chamber and tank is 26,000 gallons, and at the average rate of inflow, the dose, which is intermittently discharged on the beds, is about 35,000 gallons. The dosing tank is octagonal in plan, to better fit the intersection of the embankments, with walls 12 inches thick and roof of I-beams and 6-inch concrete slab, reinforced by expanded metal.

The continuous flow into this tank is made intermittent by the use of an 18-inch Miller siphon. The lower leg of this siphon ends in a cylinder 24 inches in diameter, with four 12-inch circular openings in the side, 90° apart. These openings are enlarged to 24 inches in diameter and connect with four lines of distribution pipes leading to the filters. Inside the four-way cylinder another cylinder with one opening is made to revolve by the rise of a float. This float carries a rack which, through gearing, transmits the motion to the vertical shaft of the inside cylinder or revolving gate in such a way that for each rise of the float the cylinder turns one-quarter of a revolution, registering in turn with each of the four openings of the outer cylinder.

The siphon, although designed to discharge at a certain depth of water, is operated mechanically by the action of a small float, which opens a valve and permits the air under compression to escape. This float can be set at any height and the size of dose thus changed as may be desired.

The connection of float with cylinder is made through a four-pawl ratchet, which, while serving to turn the cylinder on the upward motion of the float, permits the float to descend without causing a reverse movement of the cylinder. The apparatus is simple and positive in its operation, and makes possible the application of the sewage regularly during the day and night in doses of the desired amount with no attendance other than occasional oiling.

The siphon discharges at a rate varying from 10 cubic feet per

second at the beginning of its operation to 7.5 cubic feet at the end. The actual velocity in this siphon is equal to the theoretical velocity for the head between the inner and outer surfaces of water multiplied by a coefficient of 0.65.

The revolving cylinder can be turned by hand and the sewage can be flowed directly into this cylinder without passing through the siphon, in this way cutting out the dosing tank and making the discharge continuous.

The dose of 35,000 gallons, applied at a rate of 8 cubic feet per second, is well distributed over the beds 1 acre in area with a sand 0.20 m.m. "effective size." It is large enough in all but extreme conditions of temperature, when a greater dose is desirable in order to keep the beds open.

The rate of discharge is an important factor in successful distribution. At Saratoga the main pipes, outlets and carriers are all designed to carry 8 cubic feet per second. The distribution pipes are generally 24 inches in diameter, laid in trenches excavated after the embankments had been raised to an elevation 2½ feet above the grade of the pipe. Gate chambers of 8-inch brickwork and 4-inch concrete slab covers are placed opposite the center of the beds and contain the gates necessary to deflect the sewage to any bed desired.

The outlet pipes are 15 inches in diameter and protected at the outer ends by concrete abutments. From these abutments a carrier extends 180 feet across the bed. Its width is decreased from 5 feet at the embankment to 1 foot at the far end by abrupt reductions of 6 inches on each side at four points, in this way slicing off the sewage into ten parts of practically equal amount. By reducing the width a uniform depth of flow is maintained and a self-cleansing velocity made possible. Adjustable wooden gates at the outlets serve to regulate the discharge if it is desired to throw unequal quantities on different parts of the beds. The bottom of the carriers is of Portland cement concrete mixed 1:3:5, 6 inches thick, laid in sections of about 8 feet in length, with tarred paper between each section to prevent temperature cracking at random points. Iron bars were set in the concrete extending across the entire width of the carrier and turned up at the ends to serve as supports for the 2-inch plank sides. These carriers, which are the same as have been used at a number of other places, are an entire success in effecting the uniform distribution of the sewage over the beds. In the opinion of the writer, there is no other feature in sewage filtration work so important as the dosing of the filters at such a rate, in such quantities and in such a way as to quickly and evenly spread the sewage over the entire bed.

The field is divided into twenty beds—eighteen of these about 1 acre in area, the other two somewhat smaller. The problem in the grading of filter beds is to so handle the work as to get the loam and subsoil—which it is usually necessary to remove—in their final positions at one handling. Good management in this determines the cost of the earthwork, and to put a premium on such management it is the custom of the writer to specify that there shall be no second payment for material handled a second time.

The embankments were constructed of the yellow subsoil, with about 9 inches of loam on the outer surface. Great care was taken in the selection of the sand used in making fills in the beds, so that material of widely varying size of grain did not abruptly join.

Wheel scrapers, wheelbarrows and two-horse slatted bottom wagons were used in the grading. The actual cost to the contractor was about 17 cents per cubic yard—5 cents of which is chargeable to the trimming up and sandpapering of surfaces.

As has been already stated, the sand was found to extend to an unknown depth, and the water table was about 16 feet below the original surface. It was therefore decided to put in only one line of underdrains in each bed, at a depth of about 6.5 feet, and a line of 10- to 15-inch drain, at a depth of 11 feet, with which the smaller drains might connect. In the main drain manholes were placed at the junction of the laterals, and at the ends of all drains, which were turned up and carried above the surface of the beds, air vents were provided. In this way circulation of air can take place, it is believed with beneficial effect in the reduced accumulation of carbonic acid gas in the body of the filters. At Brockton, where no air vents were provided, the collection of this gas is so pronounced that a lighted lantern is extinguished in the manholes 2 feet below the surface. The introduction of manholes at drain intersections is important in the opportunity afforded of cleaning the pipes by sewer rods, should organisms develop, as sometimes happens to an extent which will almost clog the pipes. The small number of underdrains was criticised in the original plans, but it has been found that not one-quarter of the filtrate finds an outlet through these pipes, the greater part running off through the ground without appreciably raising the water table.

The total cost of the work done at Saratoga amounted to about $200,000—$65,000 of which was expended in metering the water supply and in the separation of the surface water drains. The work was let in one contract, and it is impossible without considerable labor to accurately state the separate cost of the different parts. In

Filter Beds, Looking Southwest from Septic Tanks.

View of Filter Bed in Winter.

Aërator in Operation.

round figures the pumping plant cost $11,000; the force main, $24,500; the septic tanks, $15,500, and the disposal field, $48,000.

The plant was placed in commission in July, 1903—the writer having charge of its operation until September, 1904. Systematic analyses of the sewage, septic effluent and filtrate were made during this time and gaugings of the scum and deposit in the tanks taken with a Fowler sludge gauge once each week.

The quantity of sewage varies with the season and the rainfall, and ranges from 1,250,000 gallons to double this amount. It is relatively weak except in the months of July and August, the average free ammonias equaling 2.0 parts; the total albuminoid ammonias, 0.40 parts; the oxygen consumed, 5.0 parts, and the suspended solids, 20.0 parts per 100,000. The samples from which these figures were derived, while not taken as frequently as is desirable for an exact statement of the work done, were in every case collected in small portions at intervals throughout the day and well express the conditions at the time of collection.

Since the beginning of operation all the sewage has been passed through three of the tanks, the fourth never having been filled. The time of retention in the tanks has varied from ten to fifteen hours, the shorter period being in the month of August, when the sewage is strongest, but also when the temperature is highest and the bacterial activity greatest. About 65 per cent. of the suspended solids have been removed by the septic treatment and the remainder so finely comminuted and decomposed as to nullify its capacity for forming deposits on the filters. The tanks have never been emptied and no solid matter has been taken from them. Not more than five tons of scrapings have been removed from the surface of the filters, and this only because of an excessive zeal for cleanliness.

At the present time there is 10 per cent. less solid matter in the tanks than there was one year ago, and it would seem as if the operation might extend indefinitely without drawing off any sludge. Septic treatment was begun at the time of maximum population, the result being a rapid accumulation of solids during the first two months. The action was hardly established before cold weather set in and the most severe winter in the memory of Saratoga encountered. The average of the lowest daily temperature for the three months of December, January and February was 9.3 degrees above zero; in February it was 4.8 degrees above zero. There were twenty-eight days of zero weather and a minimum of 32 degrees below zero was recorded. These figures are interesting as an indication of the temperatures at which sand filters can be successfully operated.

The scum in the tanks became frozen to a depth of several inches under the masonry roof and 18 inches of earth covering. It would seem as though open tanks in such conditions would hardly be feasible. Judging from the results at Saratoga, the process of anaërobic liquefaction is perhaps more intimately dependent on temperature than is the process of nitrification. The depth of scum and deposit continuously increased up to April, when about 44 per cent. of the entire volume of the tank was occupied by these accumulations, as measured by the Fowler gauge. At this date the temperature of the liquid in the tanks had fallen to 41° F.

The following figures show the character of the scum and deposit as measured by the gauge:

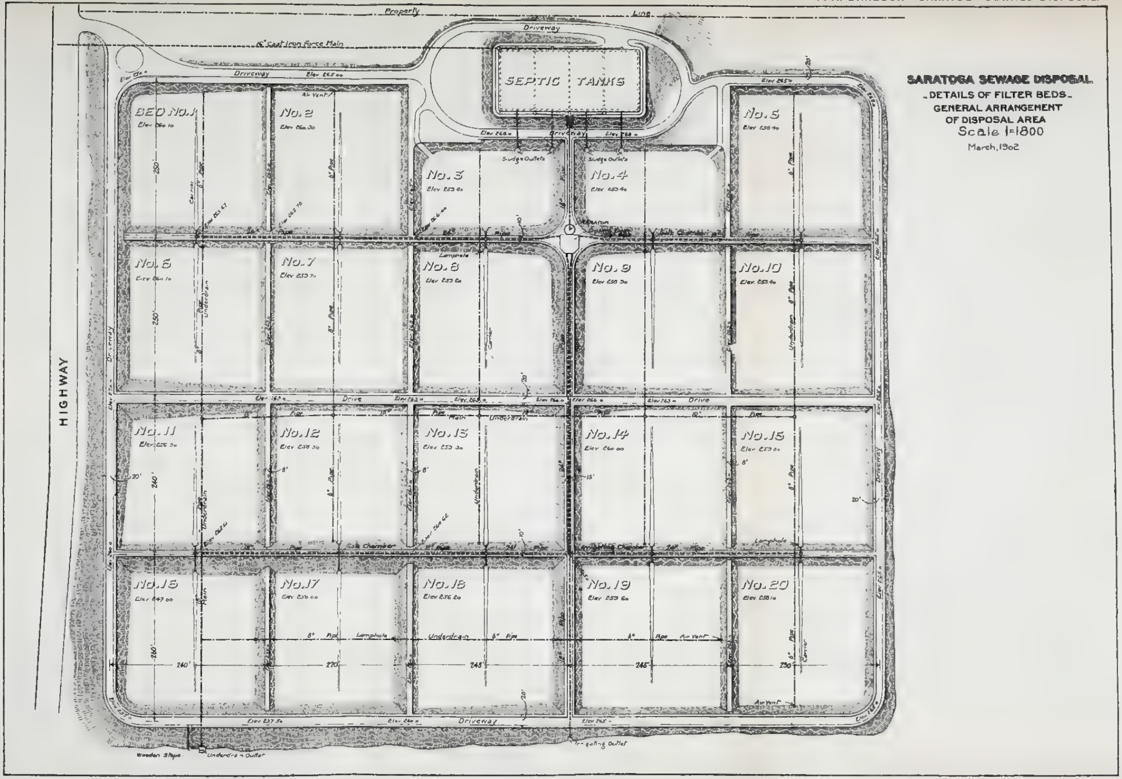
	Scum.	Deposit Per Cent.
Moisture	86.5	94.0
Volatile matter	10.0	4.5
Mineral residue	3.5	1.5

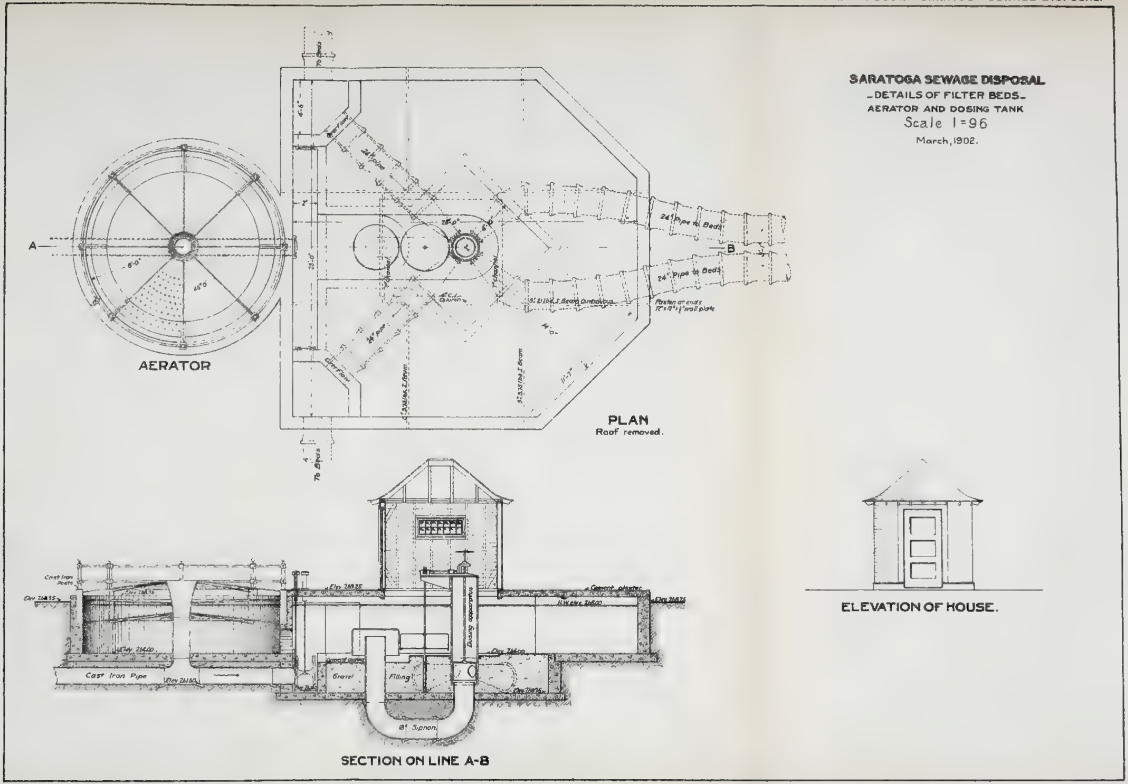
In May the temperature of the liquid in the tanks had increased to 50° F. and the scum and deposit had reduced to 35.7 per cent. of the volume of the tank. In June the corresponding figures were 59° and 24.5 per cent. In July, 65° and 23.4 per cent. In August, when the sewage reached its maximum temperature of 70°, the percentage of volume occupied by the scum and deposit had fallen to 21.4 per cent. Since then the temperature has lowered, and the accumulated solids on January 1, 1905, occupied about 25 per cent. of the tank volume.

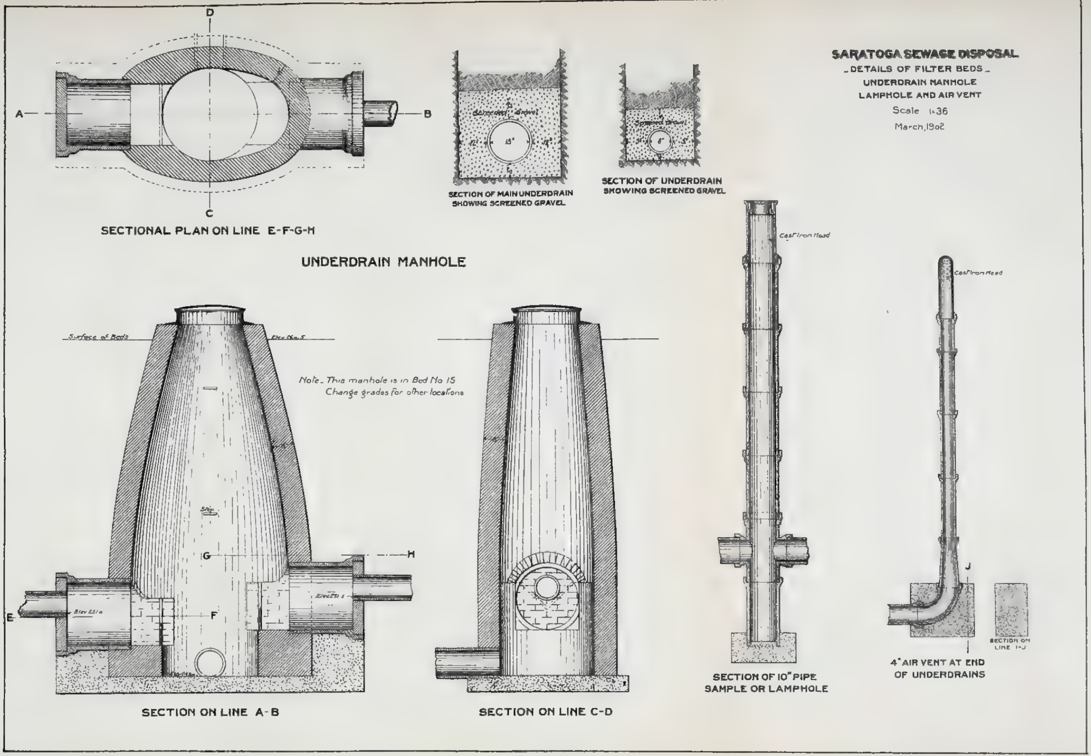
About 1,000,000 pounds of dry solid matter have entered the tanks since the beginning of operation, and 350,000 pounds of these solids have passed out in the effluent. This latter portion has been so decomposed that no visible deposit in amount large enough to attempt its removal has appeared on the beds.

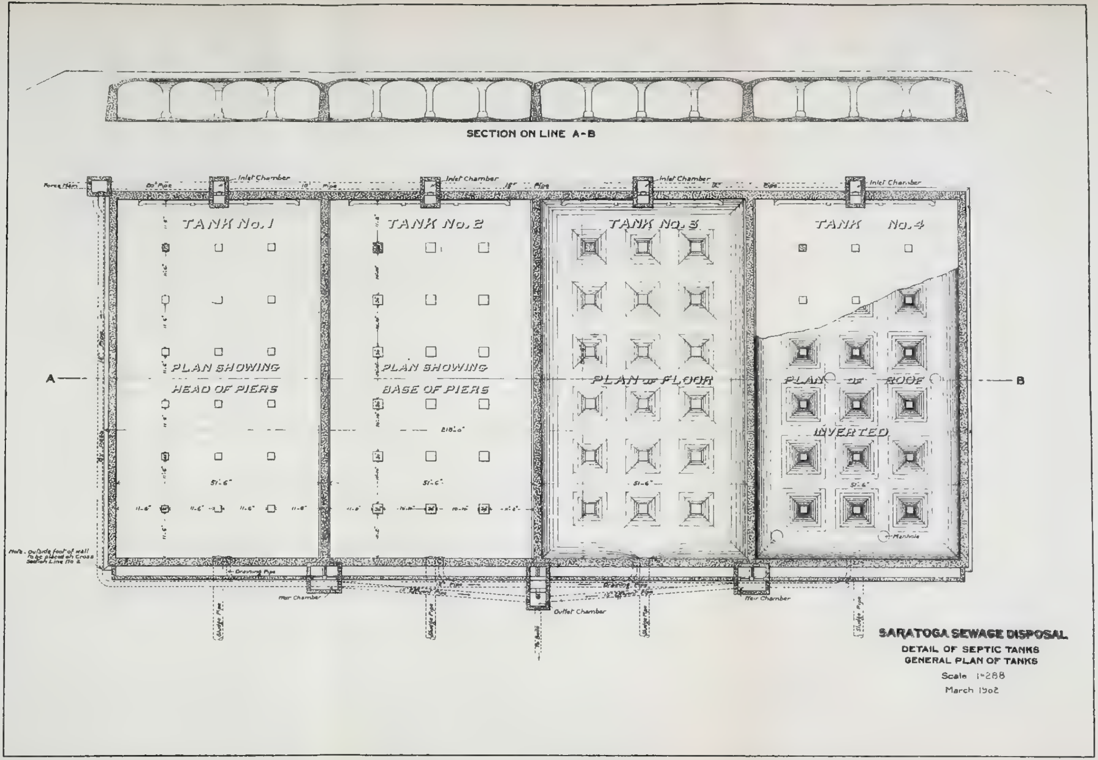
The specific gravity of the scum averages about 0.975, and of the deposit, 1.025. On January 1, 1905, about 200,000 pounds of dry solid matter remained in the tanks, of which 25,000 pounds was in the form of deposit and the balance in the floating scum. It therefore appears that 450,000 pounds of solid matters which have entered the tanks have altogether disappeared by liquefaction. The sewage is strictly domestic and probably the most favorable for successful treatment by this method.

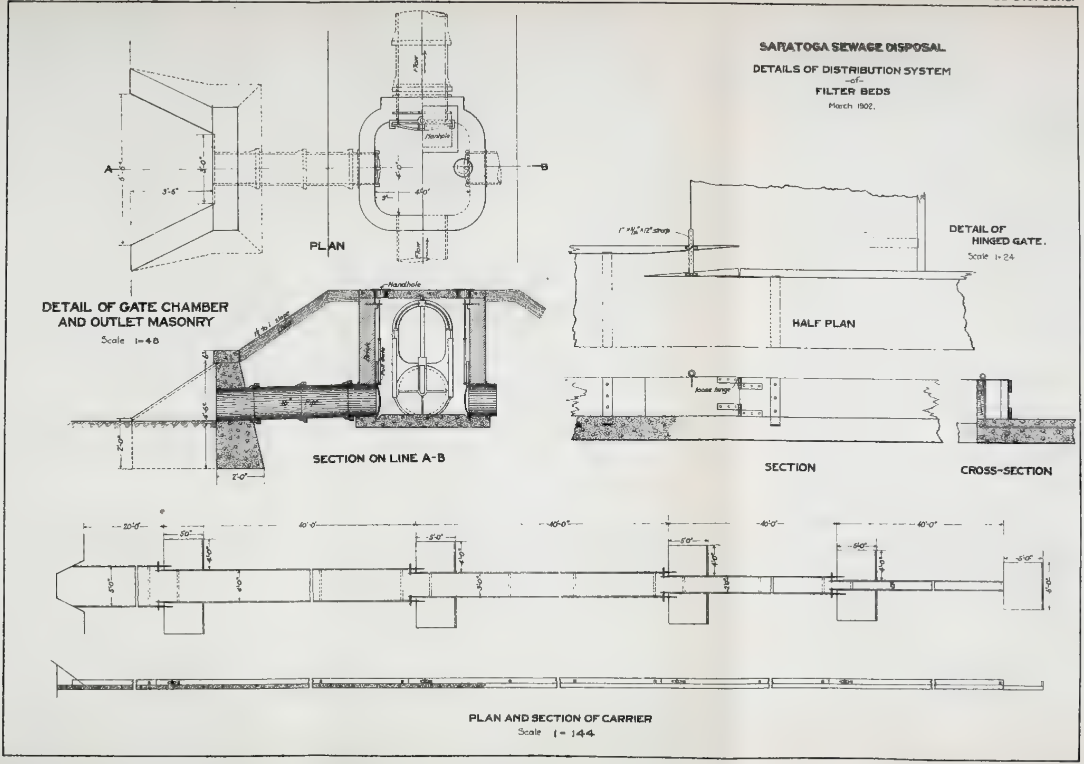
The purification of the septic effluent has varied from 99.3 per cent. in December, 1903, to 79 per cent. in March, 1904, on the basis of the free ammonias in the raw sewage and the filtrate. The nitrates have ranged from 0.5 to 2.5 parts per 100,000. In midsummer twelve beds are used daily, the gates being changed twice;


SARATOGA SEWAGE DISPOSAL.
DETAILS OF FILTER BEDS.
GENERAL ARRANGEMENT
OF DISPOSAL AREA
Scale 1=1800
March, 1902
Property Line
Driveway
SEPTIC TANKS
HIGHWAY
BED No. 1
No. 2
No. 3
No. 4
No. 5
No. 6
No. 7
No. 8
No. 9
No. 10
No. 11
No. 12
No. 13
No. 14
No. 15
No. 16
No. 17
No. 18
No. 19
No. 20
Drive
Sludge Outlets
Underdrain
Lamphole
Air Vent
Gate Chamber
Wooden Slope
Underdrain Outlet


SARATOGA SEWAGE DISPOSAL
— DETAILS OF FILTER BEDS —
AERATOR AND DOSING TANK
Scale 1=96
March, 1902.
AERATOR
PLAN
Roof removed.
24" Pipe to Beds
24" Pipe to Beds
To Beds
Over flow
Cast Iron Pipe
Gravel
Filling
Dosing apparatus
18" Siphon
Cement plaster
Cast Iron Posts
SECTION ON LINE A-B
ELEVATION OF HOUSE.


SARATOGA SEWAGE DISPOSAL
DETAILS OF FILTER BEDS
UNDERDRAIN MANHOLE
LAMPHOLE AND AIR VENT
Scale 1:36
March, 1902
SECTIONAL PLAN ON LINE E-F-G-H
SECTION OF MAIN UNDERDRAIN SHOWING SCREENED GRAVEL
SECTION OF UNDERDRAIN SHOWING SCREENED GRAVEL
UNDERDRAIN MANHOLE
Surface of Beds
Note_ This manhole is in Bed No 15
Change grades for other locations
Cast Iron Head
SECTION ON LINE A-B
SECTION ON LINE C-D
SECTION OF 10" PIPE SAMPLE OR LAMPHOLE
4" AIR VENT AT END OF UNDERDRAINS
SECTION ON LINE I-J


SECTION ON LINE A-B
Inlet Chamber
Inlet Chamber
Inlet Chamber
Inlet Chamber
TANK No. 1
TANK No. 2
TANK No. 3
TANK No. 4
PLAN SHOWING
HEAD OF PIERS
PLAN SHOWING
BASE OF PIERS
PLAN OF FLOOR
PLAN OF ROOF
INVERTED
A
B
51'-6"
51'-6"
51'-6"
51'-6"
Manhole
Weir Chamber
Outlet Chamber
Weir Chamber
SARATOGA SEWAGE DISPOSAL
DETAIL OF SEPTIC TANKS
GENERAL PLAN OF TANKS
Scale 1=288
March 1902


SARATOGA SEWAGE DISPOSAL
DETAILS OF DISTRIBUTION SYSTEM
-of-
FILTER BEDS
March 1902.
PLAN
DETAIL OF GATE CHAMBER
AND OUTLET MASONRY
Scale 1=48
Manhole
Handhole
SECTION ON LINE A-B
DETAIL OF
HINGED GATE.
Scale 1-24
HALF PLAN
loose hinge
SECTION
CROSS-SECTION
PLAN AND SECTION OF CARRIER
Scale 1=144

during the remainder of the year eight beds are used daily, one shift of the gates being necessary. The average daily amount of sewage per bed in use is about 140,000 gallons, applied in four doses. The entire field is kept in commission and the beds used alternately, so that the average rate per day for the field is about 60,000 gallons per acre. In the opinion of the writer, double this rate could be maintained with equally good results. A recording apparatus on the dosing machine indicates the number of doses applied.

The cost of maintaining the disposal field has averaged about $140 per month, of which two-thirds is expended in trimming embankments, weeding drives and other work independent of the maintenance of the bed surfaces. The cost of power for pumping has averaged about $60 per month. The engineer of the waterworks station visits the sewage pumping plant once or twice each day, and the screenings, which amount to about 170 pounds per day in all months except August, when they increased to 250 pounds, have to be removed several times weekly. Allowing $50 per month for this attendance, the total cost of pumping equals about $1300 per year, and the entire cost of operating the disposal plant, including the lifting of the sewage and its purification, amounts to about $3000 per year.

Mr. Geo. H. Wetherbee was the resident engineer in charge of construction. The disposal plant was built by Seymour & Newell, as a sub-contract from A. M. Banker, and all work was done under the authority of the Sewer, Water and Street Commission, of which Dr. D. C. Moriarta is chairman.

DISCUSSION.

Q. (By Mr. Geo. A. Carpenter).—I would like to ask Mr. Barbour how often samples are taken for analysis?

A. Once in two weeks.

Q. Is there any way of telling whether or not that deposit in the septic tank, when you reduce the accumulation in the tanks from 40 to 20 per cent., did not flow out in the effluent?

A. Only as shown by the analysis of effluent and the condition of surface of beds. We have not removed anything from the beds.

Q. Of course, if it flowed out, it would flow out as finely divided matter?

A. Yes; our analyses of the septic matter show that 35 per cent. of the solids passed out in the effluent.

Q. (By Mr. F. L. Fuller).—I would like to ask Mr. Barbour, in making that depression over the top of the piers, if a form was used?

A. No form for the upper surface was used, except a template.

Q. And that was put on as the concrete was put in?

A. Yes.

Q. I do not think you showed it in the views.

A. One view showed the depression over the piers.

Q. Do I understand that there was a frame put in to give shape to that depression?

A. No permanent frame; only a template used.

Q. Was there any trouble, owing to the thinness of the concrete of that shape, with that depression filling up?

A. No; there was no tendency to crawl; the slope was not steep enough.

Q. (Mr. Carpenter).—Did the concrete of the carriers lay directly on the sand?

A. Yes.

Q. And you have had no trouble from frost?

A. We have had no trouble yet, that I know of.

Q. I think, Mr. Barbour, you spoke about the ice forming in the septic tank, did you not, in the coldest weather?

A. I said that the scum was frozen to a depth of 4 inches in the coldest weather.

Q. How much covering?

A. The groined arch roof and 18 inches of earth.

Q. It does not seem that it ought to freeze with that covering.

A. Well, that was a remarkable winter.

Q. (A Member).—What is the depth of the sewage as applied to the bed?

A. The dose is 35,000 gallons, which would be equivalent to about an inch in depth.

Q. How soon does another dose go on?

A. This depends entirely on the amount flowing at the time. The sewage is carried around the cycle of four beds, one bed after another receiving its dose—with an interval of about forty minutes at the time of average flow.

Q. That is, each bed would get a dose once in forty minutes?

A. I am not exactly sure of these figures, but they are practically right.

Q. (Mr. R. S. Weston).—Did any disintegrated water-closet paper pass the septic tank?

A. None that was apparent.

Q. (By Mr. Freeman C. Coffin).—Did you state, Mr. Barbour, the rate at which the beds worked at any time?

A. The average daily amount of sewage has been about 1,300,000 gallons, and eight beds are used each day, except in the summer months, when twelve are used. Therefore the daily rate per bed would be about 150,000 gallons. The beds in use are changed the next day, and the average rate for the field is a little below 75,000 gallons per day per acre.

Q. Have you been able to determine whether there is a large gain in the rate of purification by the use of the septic tank?

A. It is hardly possible in a practical plant like this to prove it. The only thing we have decided in our mind is that in winter the time of absorption remains lower; it is easier to maintain the beds in winter if the solids are taken out of the sewage, and in summer the beds remain cleaner. It is a question of reducing the cost of maintaining the beds. I would not figure that a septic effluent can be purified at a higher rate than sewage from which the same percentage of solids has been removed.

Q. (By Mr. Hastings).—What has been done with the screenings?

A. They have been buried in trenches so far.

Q. Another question. When you started you spoke of a suit for damages for contaminating the brook, and, as I understood you to say, the case was based on a final discontinuance of the nuisance. How long did the court award damages—how long did they consider the nuisance would be continued?

A. The court gave the plaintiffs so much money for past damages and so much a year from the time of the trial.

Q. So much a year so long as the nuisance lasted?

A. Yes.

Q. (By Mr. Carpenter).—I want to ask Mr. Barbour how the distribution on the beds is accomplished. I notice four branches from the siphon chamber. Do you distribute to more than one bed from one chamber?

A. No; each branch from the dosing apparatus leads down an embankment, and the entire flow goes to one bed. There are four lines leading from the distributing apparatus.

Q. And how long are these four beds flowed before a change is made in the gates?

A. At this time of year the gates are shifted twice each day—in summer three times.

Q. The gates are changed twice a day?

A. Yes.

Q. Is there any difficulty in keeping a tight gate in that automatic apparatus?

A. It leaks slightly.

Q. And causes no trouble in winter on the beds?

A. No; the leakage is all taken up in the distributing pipes; it is never noticed on the beds.

Q. (By Mr. Fuller).—I would like to ask Mr. Barbour about those piers that support the roof. I think they were enlarged, but I did not notice exactly how that was done in regard to the centering. You showed one view that showed the pier heads—was the enlargement made below the centering?

A. It was made below the springing line, the pier being increased from 18 inches square to 22 inches inches square at the springing line.

Mr. Coffin.—Speaking of the construction of a roof of this kind, the last two or three cases that I have had in building a roof of that description, I have found quite an advantage in making a neck around the heads of the piers, upon which the centering is rested, and in that way avoid all strutting from the bottom of the reservoir, and I have found it a saving in expense not having the struts.

Mr. Fuller.—I should suppose, Mr. President, from the construction of that neck, it would hardly be strong enough to hold up the centering.

Mr. Coffin.—I find no trouble in that.

Q. (By Mr. C.-E. A. Winslow).—Is there much odor from the aërator in operation?

A. There is always a slight odor, but there is no more odor than from ordinary stale sewage. It is not noticeable more than 200 feet away—the odor is confined altogether within the limits of the field.

Q. (By Mr. Hastings).—I would like to ask Mr. Barbour if this aërator really pays—if it adds enough to the efficiency of the filter to pay for its cost?

A. I intimated in the paper that that could not be demonstrated in a practical plant of this kind. It would be very hard to prove it. It would have to be proved experimentally. We have always operated with the aërator in use. At Sandusky we had an aërator that did not work well, and there was a marked difference in the operation of the plant.

Q. (By Mr. Coffin).—I understand that the construction of this aërator does not increase the head pumped against, and whether you had the aërator or not the head would be the same?

A. The dose rises around the two lower leaves of the aërator to within 18 inches of the bell-mouth overflow, and the use of the aërator will usually increase the pumping head a few inches.

Q. In the construction that is a constant loss?

A. It is constant loss, but at the same time the elevation of tanks necessary for quick discharge of the sludge on the beds make necessary the same pump lift unless the sludge beds are depressed below the average level of the field.

Dr. D. C. Moriarta.—I would not have the temerity, as a novice, to attempt a discussion of Mr. Barbour's paper, were it not for the memory of the three years of uncertainty incident to determining and installing our plant at Saratoga; and of the papers read one year ago at the initial meeting of the Sanitary Section of the Boston Society of Civil Engineers. The papers mentioned were by men most eminent in the sanitary world, and their views were certainly diametrically opposite. As I recall these papers, they seem to have been the expression of prejudice rather than of study.

There is but a single feature of the Saratoga sewage disposal plant mentioned by Mr. Barbour which I feel at all competent to discuss, *i. e.,* the practical outcome of our sewage disposal plans. I would speak of the subject under three heads, maintenance, bacterial action and annoyances.

Our maintenance is almost a fairy tale.

At the pumping station, half-time of one man, per year	$300
Electrical power, one year	750
At the beds, one man in charge	660
Care of one horse that does the dragging, plowing and furrowing	200
Extra labor at the beds during the spring, fall and winter	1500

This total, small as it is, is for the first year, and will, I believe, be reduced in the future. Our expense account emphasizes one point made by Mr. Barbour, that it is wisest to use the most suitable soil for filtration purposes, even if the sewage must be lifted by means of pumps.

The operation of the plant has been practically free from annoyance. When the pumps were first started there were a few troubles, incidental to their installation. The automatic features thus far are all that we anticipated. At the beds there has not been the slightest nuisance; we are as nearly free from odor as one can imagine. This fact I would emphasize, because when I mentioned it a year ago at our meeting there was some doubt as to my sanity expressed in the faces of a few.

The value of the action of anaërobic bacteria on sewage seems to have been underestimated, because of the fact that the amount of bacterial action varies under different conditions and with different sewages. This is always bound to be the case if the sewage contains any material inimical to bacterial life. In studying this

subject intelligently, the constituents of the sewage which act as germicides and inhibit bacterial action must be thoroughly appreciated. I do not believe that the constituents of family sewage vary to any degree that would modify the bacterial action under the same relative conditions. Dilution might affect bacterial action within very small limitations, while variations of temperature will always be relatively the same. Probably all sewage from large municipalities is contaminated with chemicals; more, of course, if there are large manufacturing industries discharging their waste products into the sewers. In these instances, if bacterial action is contemplated, there must be special study to determine to what extent such waste chemical products will inhibit bacterial action. If the sewage is largely contaminated with chemicals, which are germicidal in character, there should be, in my opinion, a separate trunk sewer for the waste from these factories, which would conduct the sewage to the disposal area to be emptied on beds maintained for this particular product. Even if this sewage is not allowed to enter the tanks, it must not go on the filter beds maintained for the tank sewage, as it would reduce bacterial action in the beds, though to a lesser degree.

Another fact well known to laboratory men is of value: these same chemicals will often precipitate organic matter already in solution, thus increasing the quantity of sludge that will be deposited on the surface of the beds, or in the tanks if this mixed sewage were allowed in them.

The question of closed tanks needs only to be mentioned to be accepted, as I am sure open tanks would be a failure where the temperature goes as low as it does at Saratoga.

The value of aëration, to my mind, admits of no discussion, as all free oxygen in the sewage, while in the tanks, is essentially used up. That the septic effluent can again be readily supplied with oxygen we have demonstrated by analyzing the sewage as it leaves the tank and after it has passed through the aërator. The value of the procedure is the necessity of oxygen in the sewage for bacterial action to occur as it passes through the sand filters.

In conclusion, the facts as mentioned by Mr. Barbour, concerning the amount of sludge taken care of by bacterial action in our tanks, are correct. As nearly as we can estimate, during the year, the entire amount of sludge which has entered the tanks has been liquefied; the quantity of sludge and scum, by actual measurement, on November 1, 1904, was practically the same as that of November 1, 1903, a year previous, and the tanks have not been emptied,

nor has there been any deposit removed from the surface of the beds during this period.

Thus, I believe the treatment of normal sewage by bacterial action, aëration and sand filters solves the problen of the treatment of simple sewage; while contaminated sewage (that in which germicidal agents are present) is an indefinite proposition, and must be studied in each case by competent bacteriologists, to estimate the relative value of bacterial action, taking normal sewage as a standard.

CONCRETE-STEEL CONSTRUCTION.

By C. A. P. Turner, Member of the Engineers' Club of Minneapolis.

[Read before the Club, October 31, 1904.*]

The history of structural engineering as a science dates from the early part only of the last century. The progress made has been remarkable indeed, and the materials mainly used have varied during well-defined periods. Up to 1860 timber and cast iron were mainly used; from 1860 to 1890 wrought iron, with some cast iron was generally employed in bridges and other engineering structures; from 1890 to the present time steel has replaced wrought iron; and while, for long-span bridges, it will perhaps be some time before a more suitable metal is found, yet for short spans, buildings, warehouses and the like, the enterprise of the American manufacturers of Portland cement has placed at the disposal of the engineer a new material; reliable, if properly handled, and of reasonable cost, which bids fair to largely supplant steel in the construction of minor engineering works. Indeed, to-day, a warehouse designed for a capacity of 800 pounds per square foot of floor columns, 16 to 24 feet centers, can be built more cheaply of reinforced concrete than a wood frame and floors with similar brick walls. Where the strength required is less, timber, at the present rate, is slightly cheaper, since the cost of centering, for light and heavy construction, is the same. Still, the difference is so slight that, considering saving in insurance, owners will shortly realize that they cannot afford to continue the construction of firetraps if they are to realize the maximum profit on their investment.

In discussion of concrete-steel construction we must consider, first, the action of concrete with steel, the function of each in the combination, the problems presented by beams, slabs and columns separately, and, finally, the mixture of concrete and questions of cost in convenient placing of the reinforcement.

The strength of Portland concrete in compression is equal to that of our best building stone, with the advantage that it can be placed in a monolithic mass. The tensile strength, like stone, is greatly inferior to that in compression. The concrete yields but little —the stretch being confined to a weak section. When, however, steel is imbedded in the concrete and properly disseminated through it, Considere has shown that the deformation is some fifteen times

* Manuscript received February 2, 1905.—Secretary, Ass'n of Eng. Socs.

as great before fracture. In the tests by some American investigators, the concrete beams do not seem to fill the above condition and results should be accepted with this in mind.

In short, the condition leading to the combination of concrete and steel in a beam or girder is this: the concrete is an excellent and trustworthy material for compression and steel for tension, hence steel should be distributed in such manner as to carry the tensile chord strain and tensile web stress. To do this economically we can reason by analogy with a truss or beam. The farther from the neutral axis the more effective the unit section, hence the reinforcement for tensile chord stress should be at the bottom of the beam or as close to it as satisfactory protection against heat of fire will admit. Now the beams in a building are of constant section, and since a continuous beam is stiffer and stronger than a beam of the same section discontinuous over supports, the ideal concrete-steel beam should be continuous and the top flange reinforced over supports. Now, by analogy with the truss, that type of combination truss, in which steel is employed to carry the tensile web stress and timber the compressive stress, which requires the minimum amount of metal is the Howe type with tensile members vertical, and the economic reinforcement for our web is hence vertical. Convenience in planning of the reinforcement may, under certain conditions, of course, outweigh the gain in weight by following the lines of economic distribution of metal and modify our arrangement to some extent.

Concrete-steel construction is capable generally of as exact mathematical analysis as timber frame, and it should not be employed blindly, but carefully figured by an engineer conversant with the theory of flexure. The writer has no fine-spun theories to present which endeavor to take into consideration the tensile strength of the cement, but merely the suggestion that it is conservative to disregard it entirely and figure on the steel alone. Now, as to the form of our tension members, as engineers we would condemn immediately a section as a tension member which is nicked or has an abrupt change in section. Where changes of stress are infrequent such sections are, of course, less objectionable, but it would seem better to avoid them, providing for the shear in another manner.

If, for example, we place one plank on another of equal length and load in the center, the lower ends of the upper will project beyond the top ends of the lower and the strength of the two will be but twice that of the one. If, however, they are bolted together at the end so they cannot crawl by, the strength is approximately the

same as that of a solid beam of the depth of the two planks, though the deflection would be greater. On somewhat the same general principle we may make up for possible lack of adhesion of a plain bar by substantial end anchorage.

In bridge work we would strongly object to the use of cold-worked or torn rough-sheared metal in tension, and why should we accept such material as tension members in concrete-steel work? They will unquestionably stand a single test load well, but how will they stand repetitions of the same, or should we judge by any different standard than that applied to other engineering structures, and, if so, what is the standard to be?

We have noted that the stretch of concrete is limited, and we should consider this fact in its bearing on the grade of steel selected for reinforcement. The concrete cracks on the tension side of the beam long before the ultimate strength is reached. The exposure of the reinforcement destroys the value of the beam from the standpoint of fireproof construction. Now the modulus of elasticity of higher and mild steel does not vary greatly, hence the mild steel is to be preferred on account of its lower cost, greater reliability and ample warning it will give by plastic deformation before fracture. For the reasons given the writer would assign a fixed value for the net cross-section only of the reinforcement, whether of medium steel or stronger material, in his computations.

Viewing the question from this standpoint, the purchase of metal for reinforcement at the rate of from 5 to 8 cents per pound is rather an expensive frill for the usually level-headed contractor to indulge in when rods may be purchased at $1.30 per cwt. Pittsburg, plus half card extras.

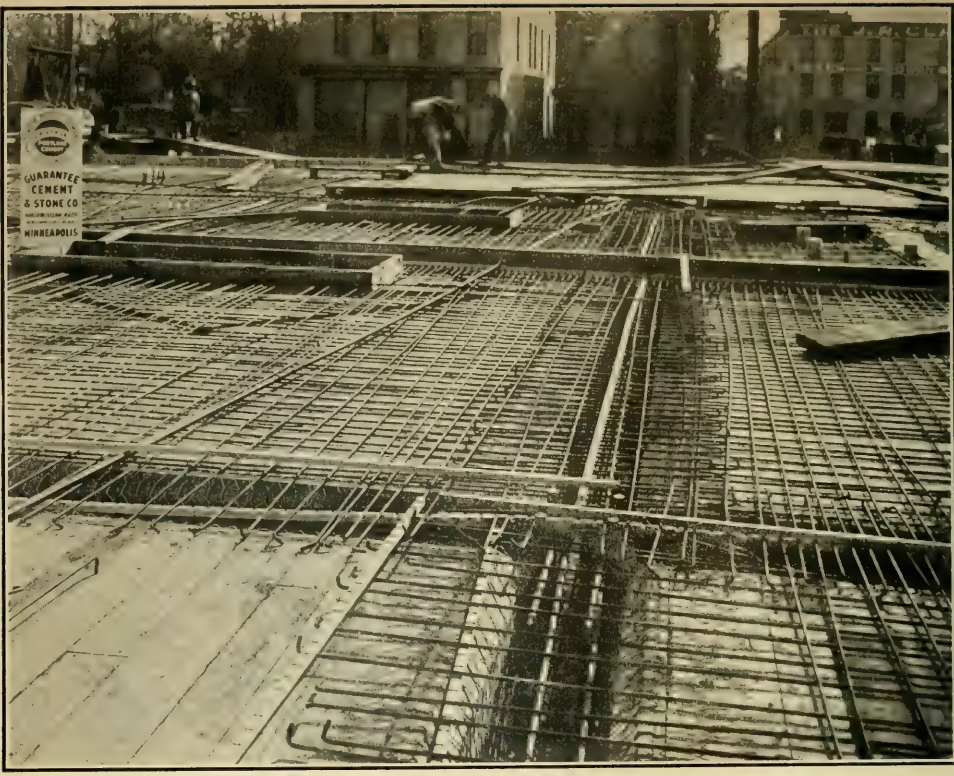
We will now take up the discussion of columns. For economy of space the columns should not have larger dimensions than those usually employed in steel construction protected by tile. Such a compression member may be subject to flexure as well as direct compression, hence the reinforcement should be distributed in the outer part of the section to be most effective. Considere has shown the great advantage to be gained by restraining the concrete laterally by winding with wire or spiral hoops.

Such reinforcement is, however, expensive, as it involves considerable labor, and for that reason, in the writer's patent system, the lateral reinforcement is in form of a grill of vertical rods placed within a riveted ring to which the rods are attached with U-bolts.

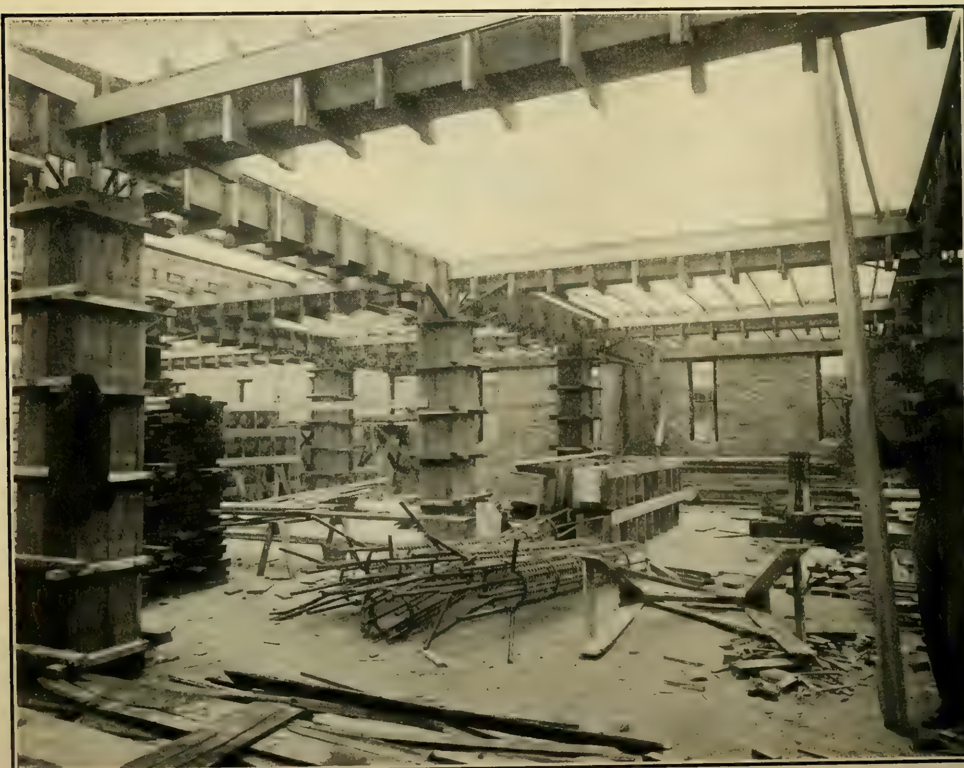
In this system of construction columns carrying moderate loads, such as 300 or 400 tons, are made up of eight rods, one of which is bent outward into each beam supported by it, which is, as far as the

View of Finished Interior,
N. W. Knitting Co. Building, Minneapolis, Minn.,
John Wunder, Contractor.

Floor Test—100 Tons on Panel 16′8″ x 15′5″. Deflection of Beams $\frac{1}{16}$″.



View Showing Floor Reinforcement.



View Showing Centering and Column Reinforcement.

writer is aware, a novel and desirable provision in way of reinforcement for shear, and adds greatly to the rigidity of the construction.

We will now turn our attention to the mixture of the concrete—the size and kind of the stone used. From the fireproof standpoint an igneous rock is evidently best, and where trap rock can be readily secured it should be preferred, though the limestone concrete is probably as good as the terra-cotta floor from that standpoint and certainly more reliable from the standpoint of strength. Limestone dust should be barred from the mixture, though granite dust or that of trap rock may be used in lieu of sand. There are a number of fine-haired theories about correct proportions of mixture. Take, for example, that given in the catalogue of the International Company: "To determine the exact mixture take a vessel full of stone; fill the space in same with sand by shaking the sand into the stone until the bulk commences to enlarge, showing no vacuum remains unfilled; then take the proportions of sand and stone; use one portion of Portland cement and two portions of sand and proportion of crushed rock as test may determine." This sounds very well, but the bulk of fine material sand will be increased little by the cement, and if we do not have an excess of the soft mixture (sand and cement) materially above that required to merely fill the voids, we will surely find them in the work.

Much has been said about dry or stiff mixtures of cement-concrete, using as little water as may be. While this is excellent practice when cement is to be placed in a temperature of 15° or 20° below zero, it is out of place in work conducted at temperatures above freezing.

The concrete should be of the consistence of brick mortar, so that it will flow slowly and require no tamping whatever. Let the water take care of the tamping—it will do it cheaply and thoroughly. Now, as to the size of the stone; about half of a size that will pass a five-eighths screen and the balance pea rock will give the most satisfactory results.

The promoters of the various systems of concrete-steel construction are doing good work in educating the general public to the use and value of concrete, though a critical analysis of not a few would make them appear to the bridge engineer as crude as the Bollman type of truss compared with those in use to-day, nor can we wonder at it when we consider the short time this class of construction has been in use. Your critical study of the various systems will well repay the time spent.

As regards experience in fireproofing steel beams and cast-iron columns, our experience is that it costs less to put up centering for

full concrete-steel construction, columns, beams and all than to hang slab centering from I-beams in place and then fireproof columns, thus avoiding the annoyance of dealing with structural ironworkers in addition to other trades on the work. The cost of reinforcement for the skeleton of a warehouse, which in steel would cost some $12,000 to $14,000, was a mere matter of some $900.

The advantages of the ferro-concrete over steel frame lies in its permanence, its perfect protection of steel against corrosion or destruction by fire, and last, but by no means least, to the peace of mind of the builder, the avoidance of complex shop details and opportunity for the annoying little errors and endless delays incident to structural ironwork.

Our experience with the cost of labor in stretching cables and the market price of same and equivalent in expanded metal has been such as to cause the abandonment of their use and the invention of a new system of slab or floor-plate construction, costing less than one-third for greater strength than those on which we have received quotations.

The accompanying photographs were taken from a building just erected in this city, using the author's patent system.

TEST OF AN INDIRECT HEATER COIL.

By S. C. Root, Member of the Detroit Engineering Society.

[Read before the Society, October 21, 1904.*]

The object of this test was to determine exactly the amount of steam condensed in an indirect coil, under varying conditions of air velocity through the coil, temperature of the entering air and depth of the coil.

For this purpose an experimental heater, with fan and engine, was set up during the cold weather of last winter, and thoroughly tested. The coil consisted of eight No. 15 regular sections, containing a total of 2400 lineal feet of inch pipe set in staggered rows. Each section of this coil contains 100 sq. ft. of condensation surface measured on the outside surface, and each section was separately valved so that any desired number of sections could be used. The fan was a 60-inch full house steel-plate blower, and was driven by a belted 5 x 5 vertical engine. The fan was arranged to draw the air through the coil, and the heated air was discharged from the fan through a galvanized iron pipe about fifteen feet long. In this pipe were placed tubes connected to a water gauge, for the purpose of measuring the air volume. This water gauge was an ordinary U-tube. On the end of the blast pipe was fitted a sliding blast gate with three different-sized openings, by means of which the discharge opening could be made full, $\frac{3}{4}$, $\frac{1}{2}$ or $\frac{1}{4}$ open. This variation in size of fan discharge had nothing to do with the heater test, but was used to obtain data from which to work up a fan test.

In this heater test, half-hour runs were made at each speed and for each heater coil depth varying from two to eight sections and for a given constant temperature of incoming air. The temperatures at various points were noted, and at the end of a half-hour run the condensation for that period was weighed. To prevent the steam from blowing through the coil and to receive the condensation, a Morehead tank trap was used. After passing through the trap the water was received in a barrel on scales. Exhaust steam from the factory engine was used entirely in this test. The outfit is quite clearly shown in the photograph.

Of course, tests of this kind have been made before, but where made by the manufacturers the results naturally have not been given out for publication. Some quite elaborate tests were made some years ago by Professor Carpenter at Cornell University, and these

* Manuscript received January 18, 1905.—Secretary, Ass'n of Eng. Socs.

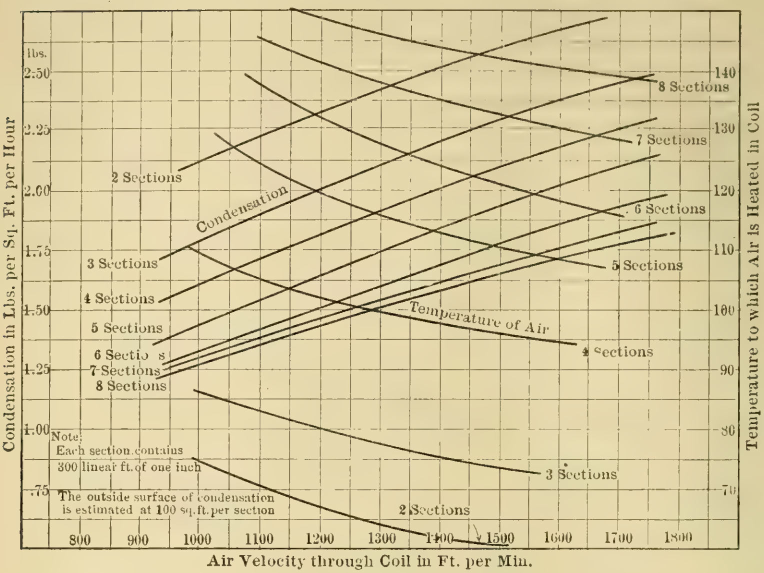


DIAGRAM 1

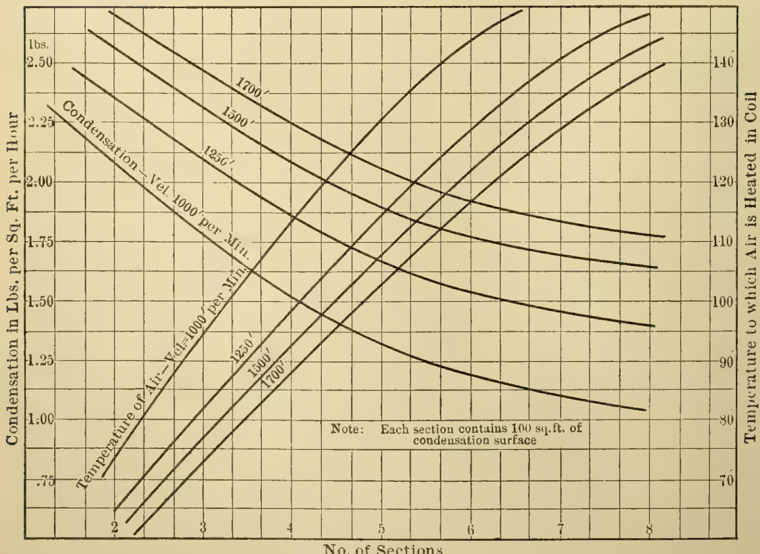


DIAGRAM 2

results were published in his book on heating and ventilating. These tests were, however, made with a constant air velocity of 1250 feet per minute in the coil. While this is undoubtedly the average air velocity in the ordinary fan heating system, this sometimes varies widely, and in the test herein described this velocity varied from 1000 to 1700 feet. Mr. Walter Snow, of the B. F. Sturtevant Co., in a lecture delivered at Cornell University some time ago, gave some diagrams showing the relative condensation and temperature for varying air velocity and coil depth. However, as the curves showed only relative values and gave no data on which to base the ratio, they were practically useless. These curves were later published by Mr. Wm. S. Munroe in his new book on "Steam Heating and Ventilation."

The following results are divided into two parts: (1) Those for air entering the coil at a temperature of 0 to 10° F., and (2) those for air entering the coil at a temperature of 40 to 50°. That is, the complete test was made in the coldest weather of last winter, and then repeated in the early spring to get another set of readings. This was to determine the condensation in the coils under different weather conditions, as these coils are often installed in buildings where fresh air is introduced at all times for ventilation, as in all public buildings as factories the air is usually re-circulated, and so enters the coil at from 40 to 60° F.

Diagram No. 1 shows the relation between condensation, in pounds per square foot per hour, and the temperature of air after passing through coils with varying air velocity. Naturally the temperature decreases and condensation increases with the air velocity increasing, as shown by these curves. The temperature increases inversely as the air velocity up to a point known as the temperature of still air in a steam coil. This is not shown by these curves, but that temperature is probably about 65°. In the other direction the temperature falls off as the air velocity increases, and by a slight stretch of the imagination we can see that the temperature becomes zero where the air velocity is infinitely great, as at such velocity no heat would be absorbed from the steam pipes.

It will be observed that the condensation curves slope gradually upward, the condensation increasing with the air velocity. With a decrease in air velocity the condensation falls off until, at zero velocity or in still air, the condensation rate equals that obtained in a direct radiator or about 0.3 pounds per square foot per hour. In the opposite direction, these curves gradually approach the horizontal, and would be parallel to the horizontal at the point where the condensation cannot be further increased by any increase in the

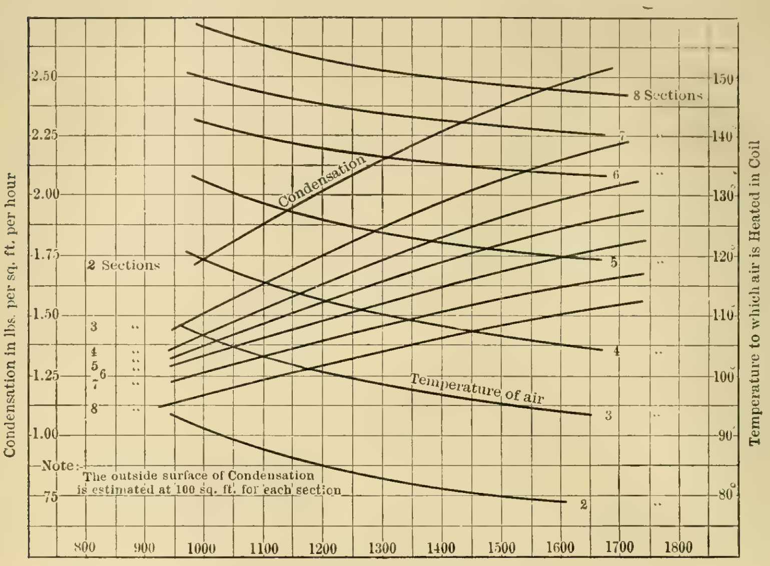


DIAGRAM 3

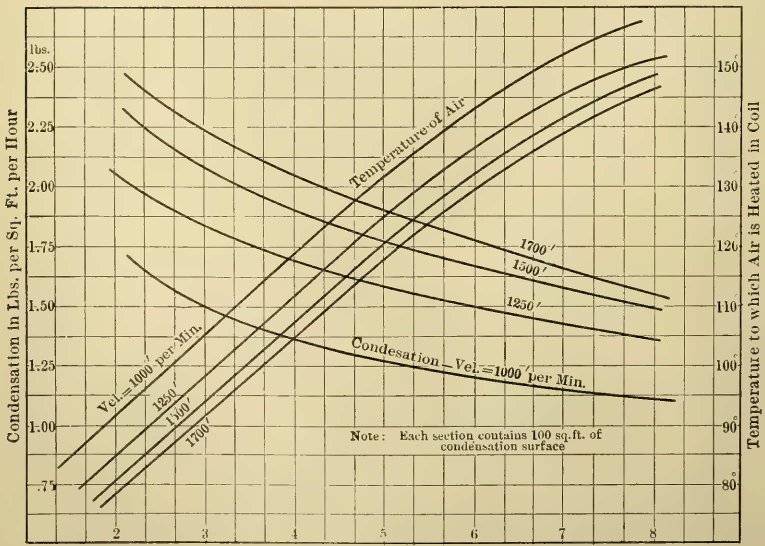


DIAGRAM 4

air velocity. From this point the curve would continue as a horizontal line.

On Diagram No. 2 this relation between temperature and condensation is shown in another way. This shows the variation for constant air velocity and varying coil depth. A separate curve is plotted for each constant air velocity. Both of these sets of curves would evidently become parallel to the horizontal if continued, indicating that there is a point beyond which an increase in coils will not increase the air temperature or rate of condensation. In theory this point would be where the air temperature was equal to the temperature of the steam. There is therefore a practical limit to the number of coils which can be placed in a bank with good economy, and this limit is about 8 or 10 sections. In practical work, coils are seldom made up in banks of greater depth than 6 sections for exhaust steam, and 4 or 5 sections for high-pressure steam. With this combination, the best average results of temperature and condensation are obtained. This point is illustrated on Diagram No. 1, where it will be observed that the temperature and the condensation rate increase with a decreasing increment beyond 4 sections. This is of course due to the fact that the temperature difference is so much less in the inner coils, and it is this fact which practically limits the depth of the coil.

Diagrams Nos. 3 and 4 again show the same relation between temperature and condensation, but in making up these curves the data used were obtained with the entering air at 40° to 50° F., which of course makes considerable difference in the results. However, the curves, of course, have the same general form, and all previous observations apply to these.

Reference has been made to some tests made by Professor Carpenter at Cornell. During the past winter, some extensive tests of indirect cast-iron sections under fan blast were made by the American Radiator Co. These cast-iron sections consisted of box-shaped sections, on the surface of which were formed small projections of diamond shape, which gave the coil extended surface. Diagram No. 5 shows graphically the relation between the results obtained by Professor Carpenter in his tests of a regular hot-blast coil, the results obtained in the test of the cast-iron indirects and the results obtained by the writer with a regular pipe or blast coil. These curves are all plotted for an air velocity of about 1250 feet per minute, and in each case the air enters at a temperature of from 40° to 50° F., except in the case of the curves shown in dotted lines, which represent results obtained with air entering at from 0° to 10°. The curves sloping upward to the right represent variations in

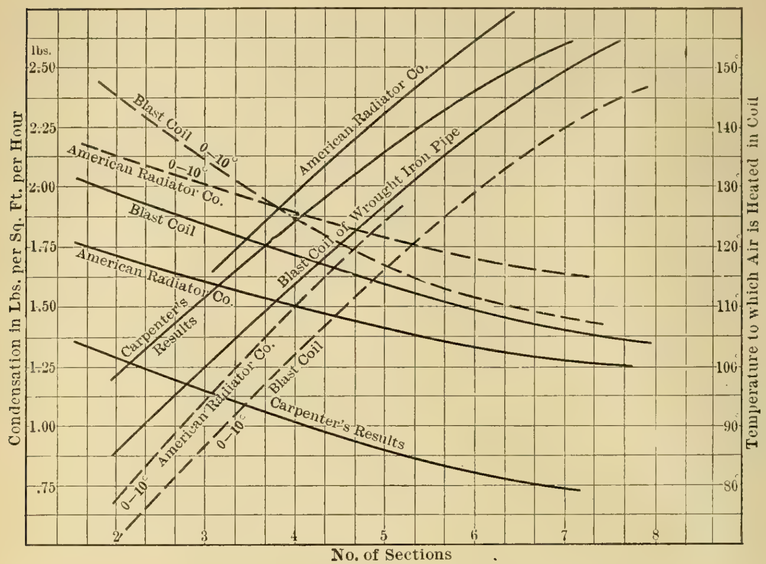


DIAGRAM 5

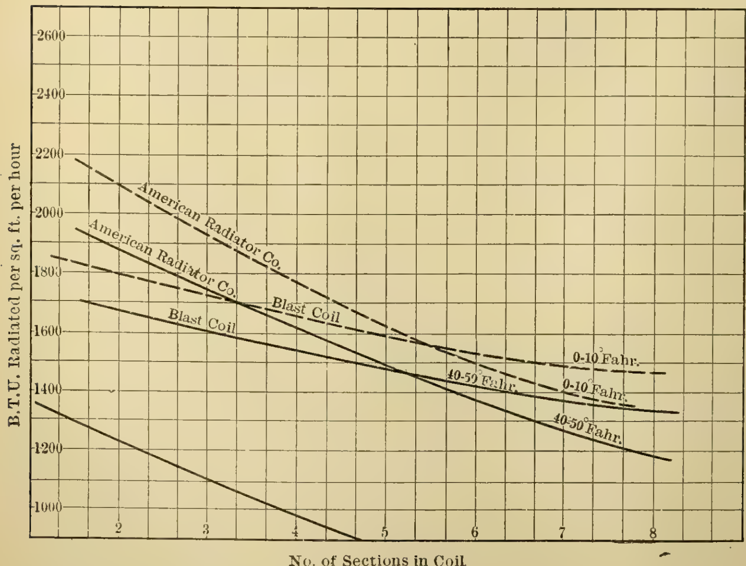
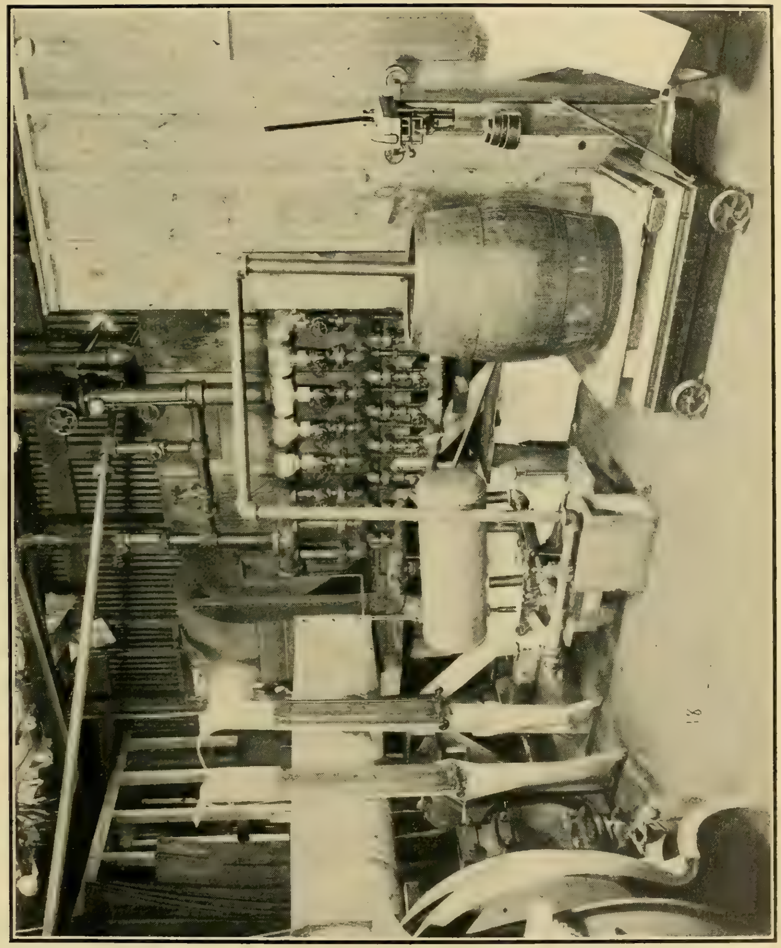


DIAGRAM 6



temperature, while those sloping downward to the right represent condensation variation. It will be noticed that both the cast-iron section and Professor Carpenter's results, as far as temperature increase is concerned, show up better than the writer's results. This, however, is due to the fact that we used entirely exhaust steam in the blast coil, while in the other two tests, live steam of at least 6 pounds pressure was used. This makes a great difference in the temperature.

However, the condensation curve shows up greatly to the advantage of the pipe coil, and this in spite of the steam pressure difference. In the cold air comparison, the curves vary less widely. I might add that in Professor Carpenter's test the air entered the coil at from 60° to 70° F., or about 15° to 20° higher than in the other two cases, which accounts for the much lower position of his condensation curve. For that reason a graphical comparison is hardly fair. If these tests could have been made under the same conditions, the curves would undoubtedly have been coincident.

The result obtained by testing different coils may best be compared by reducing the results to heat units radiated per square foot of surface per hour. This also puts the results in tangible form so that they may be used in designing coils for any purpose and under any given known conditions. Of course, all results must be compared at a common constant air velocity. I have tried to show this relation in Diagram No. 6. The lower curve shows the heat radiation from a standard hot-blast coil, as determined from Professor Carpenter's experiments.

Points for plotting this curve were obtained from data found in Professor Carpenter's late book on heating and ventilating. Professor Carpenter has also made extensive tests of cast-iron radiators under fan blast, but at such low air velocity that no comparison could be fairly made with these results. The results would, however, probably follow closely those shown above for cast-iron sections.

The 4 other curves show the variation in heat radiation for constant air velocity. The curves in full lines are for air entering the coil at ordinary temperature, while those in dotted lines are for air entering at about zero or slightly above.

These are plotted for an air velocity of about 1250 feet per minute. For any other air velocity the curves would be above or below these, as the case might be, but parallel to these.

Diagram No. 7 shows the heat radiation from a standard blast coil in B. T. U. per hour per square foot per degree difference in temperature between the steam and entering air and for a varying

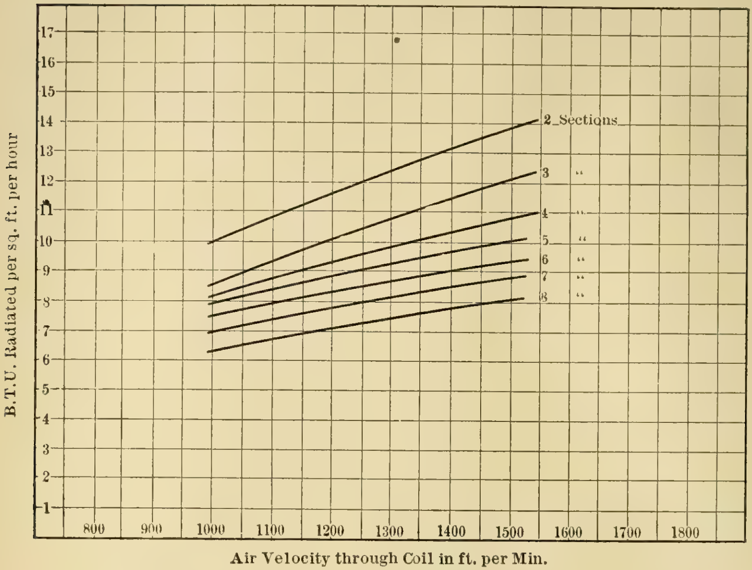


DIAGRAM 7

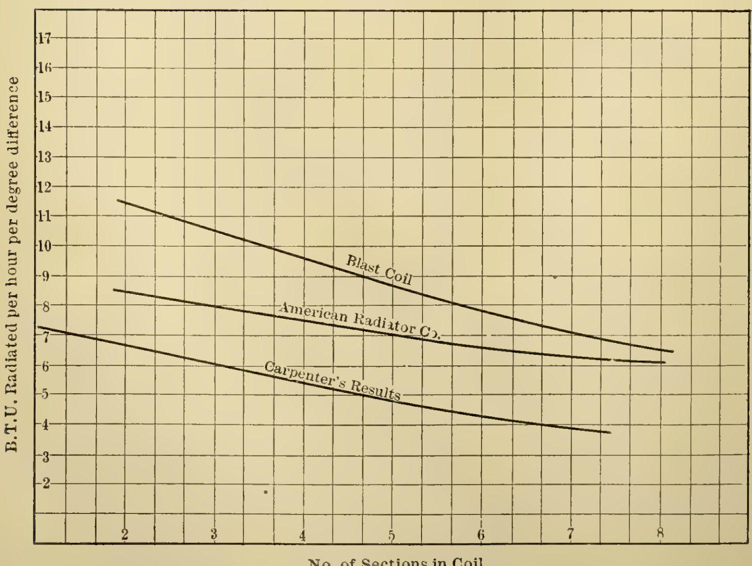


DIAGRAM 8

TEMPERATURE OF ENTERING AIR, 0 TO 10° FAHRENHEIT.

		Two Sections.				Three Sections.				Four Sections.			
Engine Speed	Revolutions per Minute	300	370	400	430	310	370	410	420	296	370	400	416
Fan Speed	" " "	625	770	834	900	646	770	854	875	616	770	833	867
Temperature of Steam	Degrees Fahrenheit	221	215	219	212	217	215	221	217	216	215	216	213
Temperature of Condensation	" "	215	211	214	210	213	212	216	212	211	210	210	206
Latent Heat	British Thermal Units	965	967	965	967	966	967	964	967	967	968	968	972
Entering Air	Degrees Fahrenheit	2	4	6	9	10	9	14	4	0	2	4	5
Temperature in Coil	" "	65	70	65	70	100	96	100	82	112	110	107	105
Temperature of Discharge	" "	60	60	60	59	80	75	80	72	85	82	85	85
Condensation—one hour	Pounds	290	464	480	520	546	580	610	664	624	720	760	780
Barometer	Inches of Mercury	29.55	28.55	29.55	29.55	28.90	28.90	28.90	29.56	29.74	29.74	29.74	29.74
Static Pressure	Full Open Discharge Pipe—inches of water	1/8	1/16	0	0	0	0	0	0	0	0	0	0
" "	3/4 " " " " " " "	3/4	1 1/4	1 1/4	1 3/8	5/8	1	1 3/8	1 3/8	5/8	1	1 1/4	1 5/16
" "	1/2 " " " " " " "	1 1/8	2 1/4	2 1/4	2 1/2	1 1/2	2 1/8	2 1/2	2 3/4	1 1/2	2 3/8	2 7/8	3
" "	1/4 " " " " " " "	2	3 5/8	5 3/4	4 1/2	3 1/4	4 1/4	4 7/8	4 3/4	2 3/4	4 3/4	4 3/4	5 1/2
Dynamic Pressure	Full " " " " " " "	5/8	15/16	1 1/8	1 1/4	9/16	15/16	7/8	1 1/4	11/16	15/16	1 1/16	1 1/16
" "	3/4 " " " " " " "	1 1/4	1 7/8	2 1/8	2 3/8	1	1 3/4	2 1/16	2 1/4	1	1 3/4	1 13/16	2 1/8
" "	1/2 " " " " " " "	1 1/4	2 1/2	2 1/2	3 1/8	1 7/8	2 3/8	2 7/8	3 3/8	1 7/8	3	3 3/8	3 5/8
" "	1/4 " " " " " " "	2 1/8	3 3/4	5 5/16	4 5/8	3 3/8	4 3/8	4 15/16	5	..	..	..	..
Velocity Pressure	Inches of Water	1/2	5/8	7/8	1	3/8	3/4	11/16	7/8	3/8	3/4	11/16	13/16
Air Velocity	Feet per Minute	2969	3160	3720	4000	2530	3596	3431	3846	2521	3596	3431	3720
Volume	Cubic Feet per Minute	8550	9000	10600	11400	7200	102000	9800	11000	7200	10200	9800	10600
Velocity in Coil	Feet per Minute	1120	1185	1400	1500	950	1350	1300	1450	950	1350	1300	1400
Condensation	Pounds per Square Foot	1.45	2.3	2.4	2.6	1.82	1.94	2.03	2.22	1.56	1.8	1.9	1.95
Radiation	British Thermal Units per Sq. Foot per Hour	1400	2240	2300	2500	1758	1860	1960	2140	1508	1742	1861	1895
Temperature Rise	Degrees Fahrenheit	63	66	59	61	90	87	86	78	112	108	103	100

		Five Sections.				Six Sections.				Seven Sections.				Eight Sections.			
Engine Speed	Revolutions per Minute	310	350	400	430	310	380	420	430	305	362	400	440	300	370	400	440
Fan Speed	" " "	646	730	835	900	646	790	876	900	636	755	835	916	625	770	834	920
Temperature of Steam	Degrees Fahrenheit	212	212	212	212	217	219	212	212	215	217	218	215	214	212	215	215
Temperature of Condensation	" "	204	204	204	204	208	209	206	206	210	211	212	210	208	202	204	206
Latent Heat	British Thermal Units	974	974	974	974	971	970	971	971	968	968	968	968	970	976	975	972
Entering Air	Degrees Fahrenheit	10	12	16	18	9	10	6	8	4	3	6	8	4	4	6	2
Temperature in Coil	" "	120	116	114	112	133	128	120	118	140	138	135	133	150	146	143	140
Temperature of Discharge	" "	100	100	98	106	120	118	105	105	124	124	124	122	134	130	128	128
Condensation—one hour	Pounds	830	860	880	976	920	998	1080	1140	972	1050	1115	1180	1090	1200	1320	1370
Barometer	Inches of Mercury	29.8	29.85	29.85	29.79	29.79	29.77	29.77	29.77	29.77	29.46	29.46	29.46	29.25	29.25	29.51	29.51
Static Pressure	Full Open Discharge Pipe—inches of water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
" "	3/4 " " " " " " "	11/16	13/16	1 1/4	1 3/8	11/16	7/8	1 3/16	1 1/4	3/4	13/16	1 1/16	1 1/4	5/8	13/16	1 1/8	1 1/4
" "	1/2 " " " " " " "	2	2 1/8	2 1/2	3	1 5/8	2 1/8	2 5/8	2 7/8	1 1/2	2 3/16	2 1/2	3 1/4	1 5/8	2 1/4	2 7/8	3
" "	1/4 " " " " " " "	3 3/4	4 1/8	4 7/8	4 3/8	3 1/4	4	4 1/2	4 5/8	2 13/16	4 3/8	4 7/8	5 1/4	3 1/8	4 1/4	4 3/4	5 3/8
Dynamic Pressure	Full " " " " " " "	3/4	11/16	15/16	15/16	1/2	5/8	13/16	1	5/8	3/4	13/16	1	11/16	7/8	1 1/16	1
" "	3/4 " " " " " " "	1 7/16	1 1/2	1 7/8	2 1/8	1 5/16	1 11/16	2 1/8	2 1/4	1 1/4	1 1/2	1 15/16	2 3/16	1 1/8	1 9/16	1 15/16	2 3/8
" "	1/2 " " " " " " "	2 3/8	2 3/8	3	3 1/2	1 7/8	2 1/2	3	3 3/8	1 3/4	2 5/8	2 7/8	3 3/4	2 1/8	2 11/16	3 1/2	3 5/8
" "	1/4 " " " " " " "	4	4 1/4	5	4 5/8	3 3/8	4 3/16	4 5/8	4 3/4	3	4 11/16	5 1/8	5 1/2	3 7/16	4 9/16	5 1/8	5 3/4
Velocity Pressure	Inches of Water	5/8	11/16	5/8	3/4	5/8	13/16	15/16	1	1/2	11/16	7/8	15/16	1/2	3/4	13/16	1 1/8
Air Velocity	Feet per Minute	3318	3486	3318	3596	3318	3780	4032	4200	2969	3477	3927	4069	2969	3637	3780	4410
Volume	Cubic Feet per Minute	9450	9940	9450	10200	9450	10800	11500	12000	8460	9900	11200	11600	8500	10300	10740	12550
Velocity in Coil	Feet per Minute	1250	1300	1250	1350	1240	1420	1500	1570	1100	1300	1470	1530	1120	1360	1420	1650
Condensation	Pounds per Square Foot	1.6	1.72	1.76	1.95	1.53	1.67	1.8	1.91	1.4	1.51	1.60	1.69	1.37	1.5	1.65	1.72
Radiation	British Thermal Units per Sq. Foot per Hour	1616	1675	1720	1900	1485	1620	1748	1845	1344	1452	1542	1631	1321	1464	1609	1665
Temperature Rise	Degrees Fahrenheit	110	104	98	94	124	118	114	110	144	135	129	125	146	142	140	142

TEMPERATURE OF ENTERING AIR, 40 TO 50° FAHRENHEIT.

		Two Sections.				Three Sections.				Four Sections.			
Engine Speed	Revolutions per Minute	306	370	400	440	315	375	410	450	300	352	386	440
Fan Speed	" " "	638	770	834	916	656	760	854	938	625	733	804	916
Temperature of Steam	Degrees Fahrenheit	212	214	217	214	213	218	216	217	212	212	212	216
Temperature of Condensation	" "	206	210	212	208	208	212	206	210	206	206	206	210
Latent Heat	British Thermal Units	971	968	967	970	971	968	973	969	971	971	971	968
Entering Air	Degrees Fahrenheit	43	45	48	30	46	50	48	52	42	48	48	44
Temperature in Coil	" "	88	85	83	80	110	108	105	102	118	115	112	108
Temperature of Discharge	" "	74	82	81	74	..	102	99	95	..	105	104	106
Condensation—one hour	Pounds	380	400	436	460	514	520	590	626	590	650	660	740
Barometer	Inches of Mercury	29.31	29.31	29.31	29.17	29.17	29.56	29.17	29.17	29.86	29.86	29.32	29.32
Static Pressure	Full Open Discharge Pipe—inches of water	0	0	0	0	0	0	..	0	0	0	..	0
" "	3/4 " " " " " " "	3/4	1	1 1/4	1 7/16	11/16	15/16	1 1/8	1 5/16	3/4	1	1 1/8	1 5/16
" "	1/2 " " " " " " "	1 11/16	2 1/8	2 7/8	3 1/16	1 3/4	2	..	3	1 1/2	2 1/8	..	3 1/8
" "	1/4 " " " " " " "	3 3/8	4 1/4	4 9/16	5 1/8	3 1/2	4 1/2	..	4 3/8	3	4 5/16	..	4 5/8
Dynamic Pressure	Full " " " " " " "	5/8	3/4	1	1	5/8	5/8	..	1	[illegible]	3/4	..	1
" "	3/4 " " " " " " "	1 1/4	1 5/8	2 1/16	2 5/16	1 1/4	1 9/16	2	2 1/4	1 3/16	1 9/16	1 3/4	2 3/16
" "	1/2 " " " " " " "	2	2 1/2	3 7/16	3 9/16	2 1/8	2 5/16	..	3 1/2	1 3/4	2 1/2	..	3 1/2
" "	1/4 " " " " " " "	3 1/2	4 3/8	4 3/4	5 3/8	3 5/8	4 7/16	..	4 9/16	3 3/16	4 1/2	..	4 13/16
Velocity Pressure	Inches of Water	1/2	5/8	13/16	7/8	9/16	5/8	7/8	15/16	7/16	9/16	5/8	7/8
Air Velocity	Feet per Minute	2918	3261	3715	3839	3100	3265	3844	3968	2728	3100	3265	3844
Volume	Cubic Feet per Minute	8300	9300	10600	10900	8850	9340	10900	11300	7760	8850	9340	10900
Velocity in Coil	Feet per Minute	1100	1230	1390	1440	1160	1240	1440	1490	1020	1165	1240	1440
Condensation	Pounds per Square Foot	1.9	2	2.18	2.3	1.72	1.74	1.96	2.08	1.48	1.63	1.65	1.85
Radiation	British Thermal Units per Sq. Foot per Hour	1845	1936	2108	2231	1663	1678	1903	2021	1432	1580	1602	1791
Temperature Rise	Degrees Fahrenheit	45	40	35	30	64	58	57	50	76	67	64	64

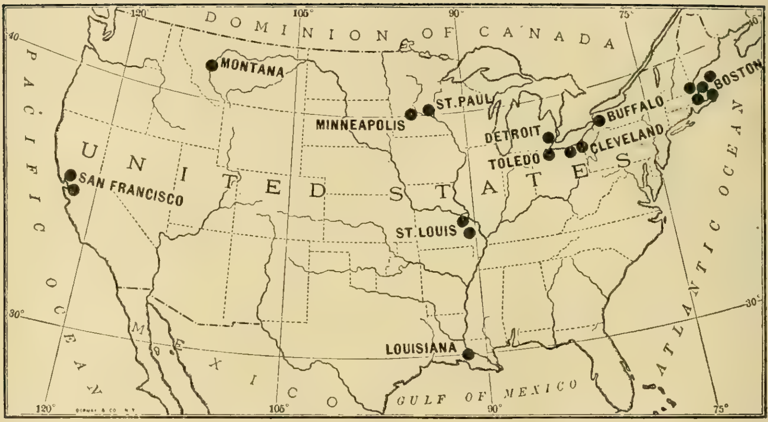
		Five Sections.				Six Sections.				Seven Sections.				Eight Sections.			
Engine Speed	Revolutions per Minute	300	360	400	450	290	350	400	470	300	370	400	440	310	370	400	460
Fan Speed	" " "	625	750	834	938	604	730	835	980	625	770	835	916	646	770	834	960
Temperature of Steam	Degrees Fahrenheit	212	212	212	217	217	217	214	215	214	212	214	212	212	212	220	218
Temperature of Condensation	" "	206	206	206	210	210	218	206	206	210	208	208	207	203	206	206	206
Latent Heat	British Thermal Units	971	971	971	969	969	971	972	972	968	969	970	970	974	971	974	973
Entering Air	Degrees Fahrenheit	46	48	48	45	49	50	48	47	50	40	40	40	40	40	38	38
Temperature in Coil	" "	132	129	125	122	148	144	138	135	154	146	142	140	160	157	153	148
Temperature of Discharge	" "																
Condensation—one hour	Pounds	716	730	750	860	760	840	862	1039	810	940	980	1060	890	965	1084	1220
Barometer	Inches of Mercury	29.32	29.32	29.32	29.32	29.46	29.46	28.83	28.83	28.75	28.91	28.91	28.91	29.04	29.04	29.25	29.25
Static Pressure	Full Open Discharge Pipe—inches of water	0	0	..	0	..	0	0	0	0	..	0	..	0	..	0	..
" "	3/4 " " " " " " "	3/4	11/16	1	1 1/4	5/8	3/4	1 1/8	1 7/16	1/2	1	1 1/16	1 1/4	9/16	3/4	1	1 3/8
" "	1/2 " " " " " " "	1 1/2	2 5/8	..	3	..	2	2 5/8	3 1/16	1 1/2	..	2 3/8	..	1 3/8	..	2 9/16	..
" "	1/4 " " " " " " "	2 7/8	3	..	4 3/4	..	3 5/8	5 5/16	..	2 11/16	..	4 7/8	..	2 3/4	..	5 1/8	..
Dynamic Pressure	Full " " " " " " "	1/2	7/8	..	1	..	11/16	7/8	1 1/8	1/2	..	3/4	..	1/2	..	7/8	..
" "	3/4 " " " " " " "	1 3/16	1 5/16	1 5/8	2 1/8	15/16	1 3/8	1 3/4	2 7/16	1	1 9/16	1 13/16	2 1/8	1	1 3/8	1 11/16	2 9/16
" "	1/2 " " " " " " "	1 11/16	3	..	3 1/2	..	2 1/4	3 1/8	4 1/16	1 11/16	..	2 13/16	..	1 5/8	..	2 15/16	..
" "	1/4 " " " " " " "	2 15/16	5 5/16	..	4 7/8	..	3 7/8	5 5/8	..	2 3/4	..	5 1/16	..	2 7/8	..	5 7/16	..
Velocity Pressure	Inches of Water	7/16	1/2	5/8	7/8	5/16	5/8	5/8	1	1/2	9/16	3/4	7/8	7/16	5/8	11/16	1 3/16
Air Velocity	Feet per Minute	2772	2969	3318	3927	2352	3318	3318	4200	2869	3150	3637	3937	2772	3318	3477	4578
Volume	Cubic Feet per Minute	7900	8460	9450	11200	6700	9450	9450	12000	8460	9000	10300	11200	7900	9450	9900	13000
Velocity in Coil	Feet per Minute	1040	1100	1250	1470	885	1240	1240	1570	1100	1180	1360	1470	1040	1240	1300	1700
Condensation	Pounds per Square Foot	1.33	1.46	1.5	1.73	1.27	1.4	1.44	1.72	1.16	1.34	1.4	1.52	1.11	1.22	1.36	1.53
Radiation	British Thermal Units per Sq. Foot per Hour	1390	1417	1456	1666	1230	1360	1400	1670	1120	1300	1360	1470	1080	1170	1320	1490
Temperature Rise	Degrees Fahrenheit	86	81	77	77	99	94	90	88	104	106	102	96	120	117	115	110

depth of coil in sections. This reduces the results to such form that they are of use in any given case where we have certain known conditions. These were plotted from data obtained with air entering at between 40° and 50°. For zero conditions these curves would of course vary slightly in position. Naturally these curves have the same general form as the condensation curves already shown.

Diagram No. 8 shows the relative heat radiation in B. T. U. for constant air velocity of 1250 feet and a varying coil depth, the radiation being given in B. T. U. per square foot per hour per degree difference in temperature between the steam and the entering air. These curves are arranged to show the relation between results obtained by the writer from the standard blast coil, results obtained by American Radiator Co. from their cast-iron sections and results obtained by Professor Carpenter in his experiments. From these we see that the heat radiation, like the condensation, varies inversely as the coil depth, and from Diagram No. 7 we also see that it varies directly as the air velocity through the coil.

The results obtained by the writer in this test of a standard blast coil of one-inch wrought-iron pipe compared with the results obtained by the American Radiator Co. with their new cast-iron section indicate that the latter company have a well-designed heater section which will give practically as good efficiency under the same conditions as will any blast coil of wrought-iron pipe now being manufactured by any of the various fan companies. This section is so designed that the air comes into intimate contact with all parts of the extended surface, which gives high efficiency.

Although these sections are of cast iron, they are tested to from 80 to 100 pounds, and so are perfectly safe for all ordinary heating work. It is more than likely that these cast-iron sections will soon entirely replace the present ordinary blast coil of wrought pipe, due to the efficiency, general adaptability and reduced cost of this new section.



MAP

Showing the locations of the Societies forming

THE ASSOCIATION OF ENGINEERING SOCIETIES.

(Each dot represents a membership of one hundred, or fraction thereof over fifty.)

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXIV. MARCH, 1905. No. 3.

HYDRO-ELECTRIC POWER DEVELOPMENT AND TRANSMISSION IN CALIFORNIA.

BY ROBERT McF. DOBLE, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Autumnal Meeting of the Society, December 1, 1904.*]

THIS paper is a brief historical review of the art of electrically transmitting to market the power of California mountain streams. Unknown less than twenty years ago, the progress made in this art in California during the last decade is so remarkable as to attract the attention of engineers the world over.

The business of commercially transmitting power over long distances is due to the development of alternating current electrical apparatus and the practicability of obtaining very high voltages, which are easily converted as circumstances may require.

The locations of the principal plants and transmissions are shown on the accompanying map, Fig. 1, and the principal data of each are given in the diagram, Fig. 2.

POMONA.

The Pomona plant, which went into operation early in 1893, was the first alternating current transmission system in California, and it converted the energy of San Antonio Creek to the uses of the people of Pomona and San Bernardino. Water, under a head of 402 feet, was utilized, and single-phase electrical current was generated at a pressure of 1000 volts. At that time the high-tension transformer, as we now have it, was unknown, and, to get the pressure of 10,000

* Manuscript received February 13, 1905.—Secretary, Ass'n of Eng. Socs.

volts desired for the transmission, the generator pressure was stepped-up to 500 volts by each of twenty oil-insulated transformers, connected in parallel on the generator side and in series on the transmission side. The twenty 500-volt coils in series gave 10,000 volts for transmission. The $28\frac{3}{4}$-mile line to San Bernardino was longer than any other commercial line in the world. The wires were carried on flint-glass insulators of a special design, which became known as the Pomona type. Much credit is due to the builders of this plant for their ingenuity and perseverance in overcoming obstacles in a field that was entirely new.

REDLANDS.

The Pomona plant was followed almost immediately by the Redlands plant, which was put into operation in September, 1893. It was the first to use the 3-phase system and it marks the beginning of the present form of Californian power transmission.

The energy of water from Mill Creek, under 377 feet head, was used to drive the generators.

The first generating unit installed has the tangential water wheels, outside the building, mounted on a shaft which extends through the wall and is connected, by means of a coupling, to the generator shaft, there being five bearings in line.

Fig. 3 is a view of the interior of the power station. The generators are 250-kilowatt, 50-cycle, 2500-volt machines. They were the first 3-phase generators built in the United States, and they have been in service more than 11 years. They were designed to run in parallel, a thing at that time declared by some to be absolutely impossible.

Power was at first transmitted at the generator pressure a distance of $7\frac{1}{2}$ miles to Redlands, over two 3-phase circuits of No. 0, B. & S. gauge, bare copper wire, supported on deep-groove double-petticoat glass insulators. The principal power customer was the Union Ice Company, where a 120-kilowatt synchronous motor was installed. This motor operates at 2300 volts. It was the first of its kind built in the United States, and it is still running.

The three transformers shown were installed in 1896, when the 22-mile transmission to Riverside was built. These are 100-kilowatt capacity each, and were a radical departure from the conventional practice of that time. Each consists of two units in series, on both high- and low-tension sides, the coils being immersed in oil in a water-jacketed cast-iron tank. They raise the pressure from 2500 to 11,000 volts.

FIG. I. SKETCH MAP SHOWING THE LOCATION OF THE PRINCIPAL HYDRO-ELECTRIC POWER TRANSMISSIONS IN CALIFORNIA.

DATA OF THE PRINCIPAL TRANSMISSION PLANTS IN CALIFORNIA

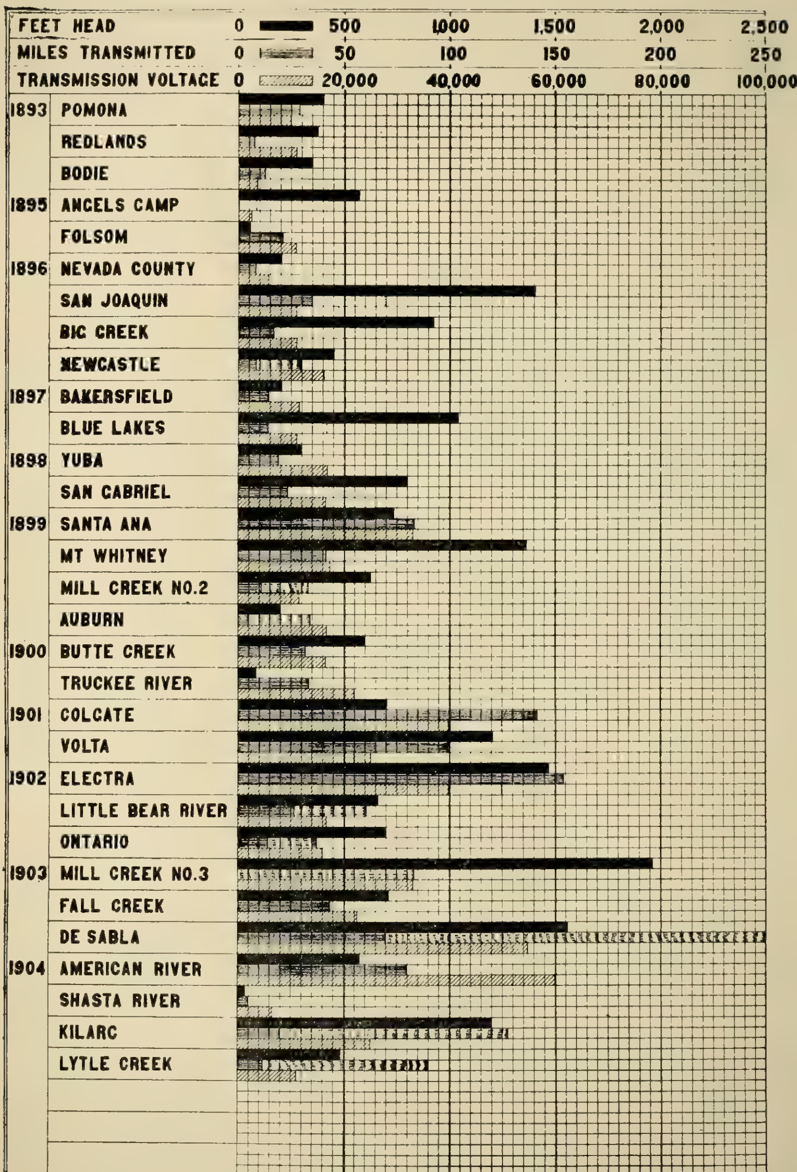


FIG. 2.

The original switchboard was a framework of redwood, with the instruments mounted thereon, including an early form of acoustic synchronizer, known as the "growler." Each of the two phases to be synchronized operated upon a sheet-iron diaphragm, the two diaphragms being separated several inches, and inclosed, facing each other, in a brass cylinder. It was expected that the operator could detect synchronism by the sound emitted through the little hole in the middle of the brass tube. Unfortunately, the various harmonics generated made it impossible to distinguish, with any degree of accuracy, when the machines were in synchronism, and the little instrument is preserved for its historic interest only.

The famous Redlands type insulator was developed, and its virtues proved on the transmission to Riverside, which was completed in December, 1896. This was the first high-tension insulator of porcelain, and the forerunner of the best high-tension insulators now in use. This plant has been remodeled and is in service.

BODIE.

About this time, 1893, a small plant was put into operation in Mono County. Water from Green Creek, under 350 feet head, was utilized to run a 120-kilowatt single-phase generator. Current was transmitted, at the generator pressure, 3500 volts, over a line 12½ miles long, to the 20-stamp mill of the Standard Consolidated Mining Company, at Bodie, where it was successfully used for lighting and power.

ANGELS CAMP.

A small beginning was made, in 1895, by the Utica Mining Company, who used water from the North Fork of the Stanislaus River, under 570 feet head, to drive a tangential wheel belt-connected to a 75-kilowatt single-phase generator. Current was transmitted, at 2500 volts, about a quarter of a mile, and used for lighting the company's mine. This installation was superseded, in 1899, by a larger plant, which, besides supplying light and power for the mine, sends current to the town of Angels Camp, a distance of 8 miles, at 16,500 volts pressure.

FOLSOM.

The next important plant was completed at Folsom, on the American River, in July, 1895. A heavy masonry dam, shown in Fig. 4, was built, and a canal, 50 feet wide and nearly 2 miles long, was made along the east bank, conveying the water to the power house. An interesting feature of the dam is the great shutter,

located on its crest and raised or lowered by hydraulic rams, by means of which the storage capacity of the dam is greatly increased without necessitating extra strength to withstand the freshets of the rainy season. At the lower end of the canal there is a double forebay, conducting the water to the electric power plant.

The hydraulic machinery consists of four pairs of 30-inch turbines of 1200 horse-power capacity each. These run at 300 revolutions per minute, under a 55-foot head. Each pair of wheels has a 10-foot steel-banded flywheel weighing 10,000 pounds, and is direct-connected to a 750-kilowatt, 3-phase generator, the shaft extending through the wall of the power house into the generator room. The generators appear in Fig. 5, and are said to have been the largest 3-phase machines made up to that time. Current is conducted through a marble switchboard, with a double set of busbars, to the air-blast transformers upstairs, where the pressure is raised from 800 to 11,000 volts for transmission to Sacramento. All switching is done on the low-tension side.

The transmission line is 21½ miles long and consists of four separate 3-phase circuits on two separate pole lines, one on each side of the county road. Redlands type insulators were used.

This plant was the first transmission system built on the Pacific Coast to carry a street-railway load, and it proved a complete success. It has been merged into the system of the California Gas and Electric Corporation, and still is in regular operation.

NEVADA COUNTY.

The Nevada County plant is especially interesting as the forerunner of the most extensive hydro-electric transmission system in the world, namely the "Bay Counties" system. The original plant was started in February, 1896. About 6000 miners' inches of water were diverted from the South Fork of the Yuba River, conducted in a wooden flume along the side of the cañon about 3½ miles to a 48-inch steel-riveted pipe leading to the power house, 206 feet below. The pipe terminates in a 48-inch steel distributor, commonly called a receiver, having lateral branches leading to the water-wheel nozzles. The capacity of the plant was 1000 horse power until the spring of 1897, when it was increased to 2000 horse power. Provision was made for four generating units, each consisting of two double-nozzle tangential water wheels on the same shaft, direct-connected through a coupling to a 350-kilowatt Stanley inductor-type generator, which delivers 2-phase current at 5500 volts and 16,000 alternations per minute. There were no raising

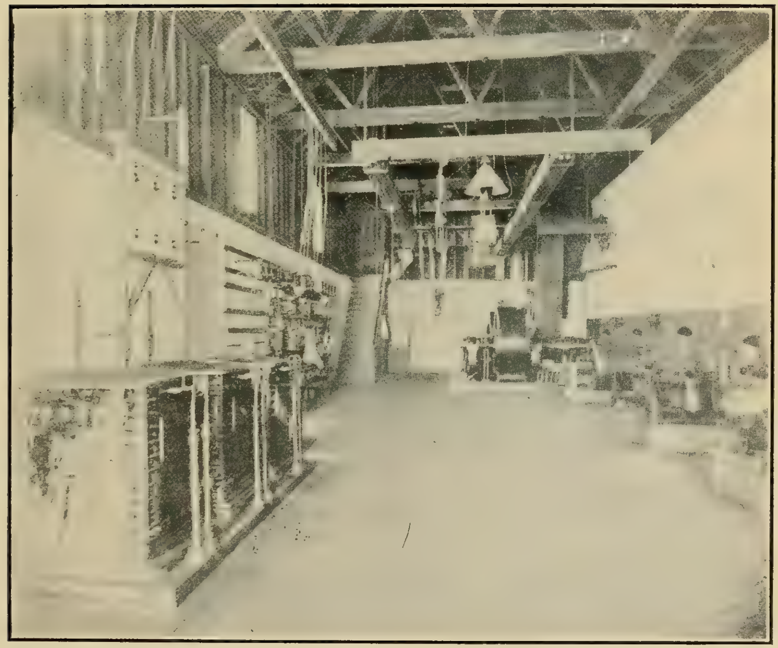


Fig. 3. Interior of the Original Redlands Plant.

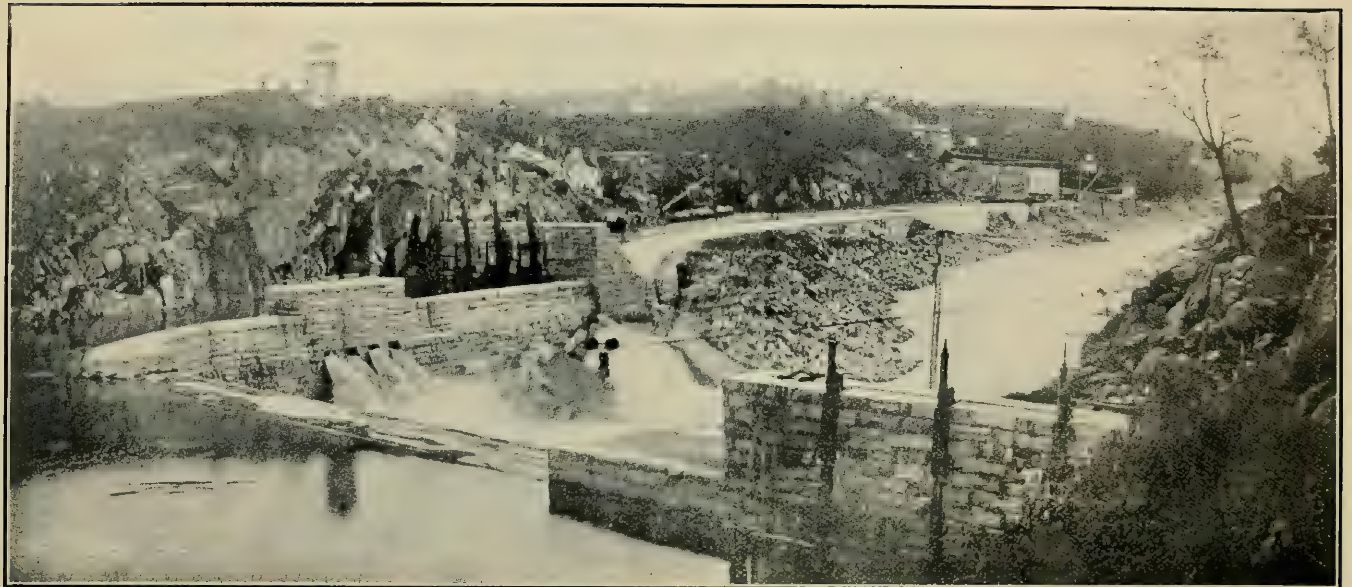


Fig. 4. The Dam and East Side Canal at Folsom.

transformers, current being sent out at 5500 volts over two 2-phase 4-wire circuits to Nevada City and to Grass Valley, a little less than 8 miles away. This was the first 2-phase transmission system in California, and, although the transmission line has been entirely rebuilt, it is interesting to notice some of its details. A galvanized barbed wire was placed on the tops of the poles and grounded every few poles with the hope that it would effectually prevent disturbances due to lightning. The two telephone wires were placed one above the other on the same poles that supported the transmission wires. Both telephone and power circuits were transposed. Low-resistance telephone instruments were tried at first, but were found to be very unsatisfactory.

In 8 months from the time of beginning work on this plant, current was being delivered to the customers. Considering the difficulties overcome and the state of the art at that time, this was remarkably quick construction.

The water wheels at this plant have been replaced and high-frequency 2-phase current is still being supplied to numerous mines. When the demand for electric current became greater than the capacity of this plant, a high-frequency 2-phase generator was installed at the Colgate plant, which has since been running in parallel with the generators in the Nevada County plant.

SAN JOAQUIN.

Fresno and vicinity are supplied with electric power from the San Joaquin plant, which went into operation in May, 1896.

At that time this plant had the distinction of utilizing the greatest hydraulic pressure and of having the longest electrical transmission in practical use.

Water is taken from two branches of the North Fork of the San Joaquin River and conducted through 7 miles of ditch to a reservoir 1411 feet above the power house. The pressure pipe is 24 and 20 inches in diameter, and is provided with air and relief valves. The lower part consists of 20-inch lap-welded pipe with flange joints, terminating at the bottom in a 30-inch riveted steel receiver made of $\frac{3}{4}$-inch plate, and provided with relief valves. There were three tangential water-wheel units, located under the receiver and over the single tail-race. The wheel shafts are extended through the wall of the power house and coupled directly to the generator shafts. The generators are 340-kilowatt, 60-cycle, 3-phase, 700-volt machines and run at 600 revolutions per minute. Two exciter units are driven by water from a separate tank part way up the pipe line.

The tank is filled from the main pipe and supplies a separate and constant pressure, which is used for the water-wheel governors also. Current was originally stepped-up to 11,000 volts and transmitted 35 miles to Fresno. In 1898, the line was extended to Hanford, making a total length of 69 miles, and the transformer connections on the high-tension side were changed from mesh to star, giving a transmission pressure of 19,500 volts. This brought the San Joaquin plant again in the lead for both distance of transmission and line voltage.

When this plant was put into operation, some rather interesting things happened as a result of the enormous hydraulic pressure utilized. After two days' operation, the concrete lining of the tail-race was worn away and the water began coming through fissures in the rock into the power house. The concrete was replaced and floored over with 3-inch planks, sheathed with $\frac{3}{8}$-inch steel plates. In less than three days a $\frac{1}{4}$-inch jet which had been left running had worn through the steel plate, through the planking and into the concrete again. A cast-iron plate $1\frac{1}{2}$ inches thick was then fed to the jets as fast as it wore away.

In 1902, new water wheels were installed and a fourth unit added. These new wheels were the first to be equipped with the needle regulating deflecting nozzle. At the same time a second tail-race was dug parallel to the first and opening into it.

BIG CREEK.

In June, 1896, the plant of the Big Creek Power Co. was put into operation. Water was conveyed about 2 miles in a wooden flume, and a head of 923 feet was utilized, the water being brought down through 1935 feet of wrought-iron pipe, with leaded and banded joints, to a 500-horse-power tangential water wheel direct-connected to two 150-kilowatt, 2-phase, 1100-volt generators, running at 600 revolutions per minute. The pressure is raised from 1100 volts, 2-phase, to 11,000 volts, 3-phase, for transmission 17 miles to Santa Cruz. The transmission line consists of two 3-phase circuits of No. 5 bare copper wire, and originally was transposed at every pole. The telephone wires are supported on brackets just below the lower cross-arm and transposed every fifth pole.

The location of the original transmission line along the ocean beach for about 15 miles of its length proved to be a matter of exceeding annoyance in the frequent shut-downs of the service that were caused by the fogs, sea spray and dust, which settled on them and resulted in the frequent burning out of insulators, pins, cross-

arms and even of the poles. This condition led to the building of a new transmission line placed well inland, far out of reach of the deleterious influences found on the coast.

NEWCASTLE.

In 1896, the Central California Electric Company, which is affiliated with the South Yuba Water Company, began to distribute electricity from its plant at Newcastle.

The hydraulic system of the South Yuba Water Company is one of the most extensive and most completely developed in the State, comprising as it does a very large watershed, 20 reservoirs in the high mountains and 450 miles of canals and ditches.

The Newcastle plant utilizes a fall of 452 feet in the main canal of the South Yuba Water Company to drive tangential water wheels direct-connected to 400-kilowatt, 2-phase, 60-cycle, 500-volt generators. The capacity of the plant is about 1000 horse power. The pressure is stepped-up from 500 to 15,000 volts for transmission 29 miles to Sacramento. This was the highest voltage then in use in California.

The demands upon this plant became so great that in 1899, to help carry the peak load, a small auxiliary water-power plant was built near Auburn, utilizing a head of 200 feet to operate a 500-kilowatt, 2-phase unit, the pressure being stepped-up from 550 to 15,000 volts for transmission. The two plants are operated in parallel. The line to Sacramento was completed in 1897, and on starting the Auburn station, the extreme length of transmission reached 34 miles.

BAKERSFIELD.

In March, 1897, the 1500-horse-power plant of the Power Development Company was completed. Water is diverted from the Kern River without dam or headworks, and at first was conveyed in a covered wooden flume about 1½ miles along the precipitous sides of the rocky Kern Cañon to the head of the pressure pipe, as appears in Fig. 6.

The water descends through 540 feet of 66-inch riveted steel pipe to a steel distributor, provided with a 16-foot air chamber at one end, which has since been removed. The head utilized is 202 feet. Water is taken from the distributor through laterals to two sets of tangential water wheels, each set direct-connected to its generator through a spring-actuated transmission dynamometer. This dynamometer operated a hydraulic valve which changed the

quantity of water impinging upon the wheel in proportion to the power transmitted and thus acted as a speed regulator.

The two generators are 3-phase, 450-kilowatt machines. Air-blast transformers raise the pressure from 550 to 11,500 volts for transmission 14½ miles to Bakersfield. The transmission was later extended to Stockdale, 24 miles from the power plant.

Although the flume was well constructed it was difficult to maintain it because of rock slides, so in 1900 the company, at an expense of $140,000, drove a tunnel through the mountain to supersede the flume. From this time the flume as a conveyor of water for power plant has declined in favor among leading engineers.

This plant is still running. It is the first one built expressly for operating centrifugal pumps for irrigation work.

BLUE LAKES.

The Blue Lakes plant, put into operation in August, 1897, marks the beginning of a noteworthy enterprise, which was the basis of the first long-distance transmission line into San Francisco. The founders of the company were the men identified with the old Blue Lakes Water Company, whose hydraulic system embraced 300 square miles of the watershed of the Mokelumne River, and included 11 reservoirs in the high Sierras.

The Blue Lakes plant was most carefully designed and constructed and in it we find many features that have since come to be standard practice. Water was taken from the Butte Ditch, near the Slabtown and Petty reservoirs, and conveyed through a steel pipe line 3240 feet long to the water-wheel nozzles 1043 feet below.

A profile of the system is shown in Fig. 7. The pipe tapers, being 48 inches in diameter at the top and 22 inches in diameter at the bottom, where the thickness is ½ inch and the pipe is lap welded. A noteworthy feature is that there are no horizontal bends in the pipe line and that it was firmly anchored to bed rock and completely buried. This was the first of the power-plant pipes installed without the customary air valves, relief valves, air chambers or receiver. The customary receiver at the lower end of the pipe was replaced by branches leading directly to the nozzles. This design reduces the hydraulic loss to a minimum.

The generating units, as shown in Figs. 8 and 9, were a marked improvement over what had preceded them.

The water wheel and the electric generator were placed as close together as possible; the water wheel being mounted upon

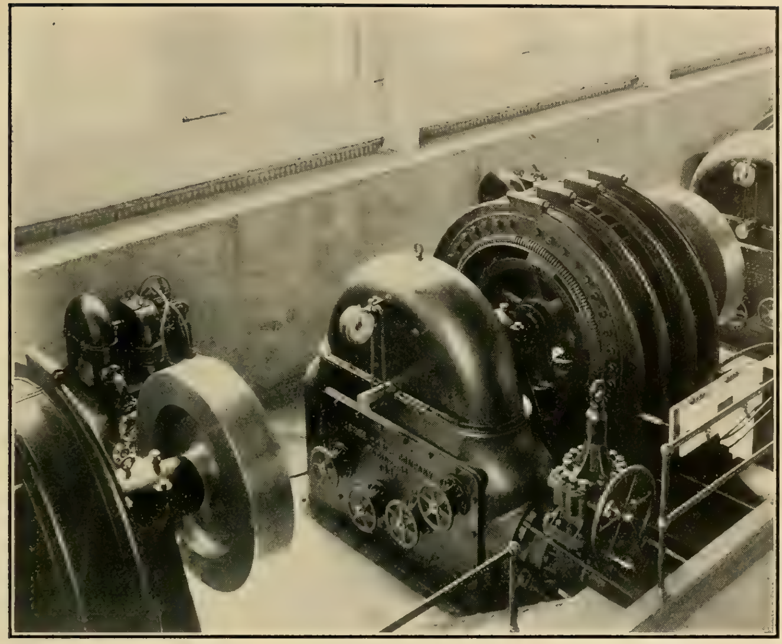


Fig. 8. Generating Unit in the Blue Lakes Plant.

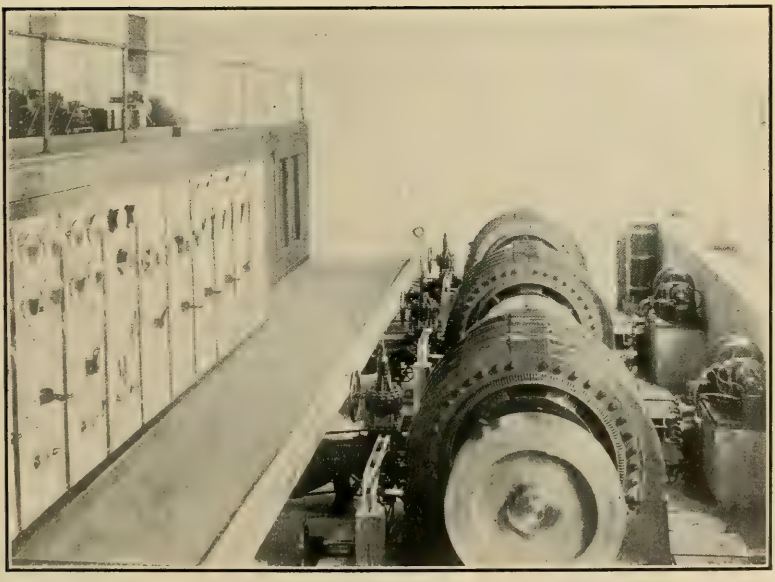
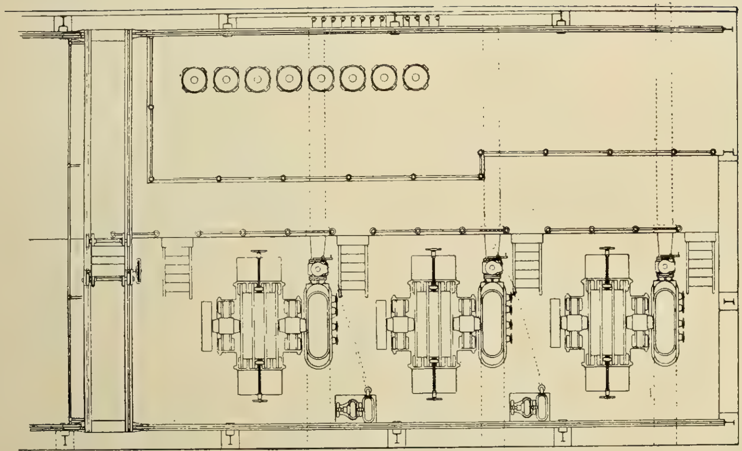
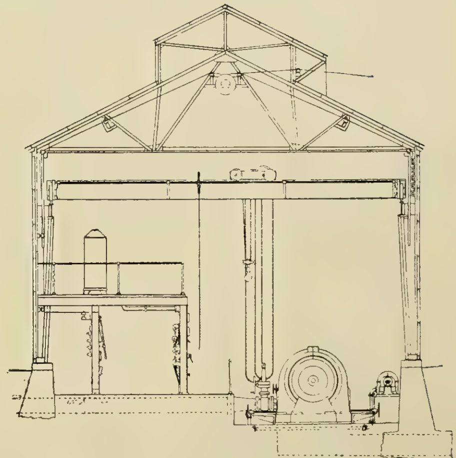


Fig. 9. Interior of the Blue Lakes Plant.



Ground Plan of the Power House.



Sectional View of Power House.

Fig. 10. Plan and Elevation of the Blue Lakes Plant.

the extended end of the generator shaft, overhanging one of the two bearings. This makes the most compact unit possible and the design has become standard practice.

A separate tail-race was provided for each water wheel, and the advantage of this arrangement has become evident.

The building was a steel frame covered with corrugated iron and lined with asbestos. It was noticeable for the compact, logical arrangement of the machinery, as shown in Fig. 10. The three generating units were in a row, the exciter units being on the same floor level but raised on pedestals to make them conveniently accessible. The switchboard was located behind the generating units on a higher floor, with the high-tension panels behind the low-tension panels. The step-up transformers were located on framework above the switchboard apparatus. The transmission line was originally 2-phase, 4-wire, and extended through Amador and Calaveras Counties to various towns, mines and mills. This line was reconstructed into a 3-phase line by the Standard Electric Company and is now a portion of the Standard System of the California Gas and Electric Corporation.

BROWNS VALLEY.

In 1897, the men who built the Nevada County Power Plant organized the Yuba Power Co. and began building a plant to supply current to Browns Valley and Marysville, which was finished in the incredibly short time of 125 days, and went into operation in March, 1898. A drop of 300 feet in the main ditch of the Browns Valley Irrigation System is utilized. The water descends through a 42-inch riveted steel pipe to a steel receiver. About 2000 horse power is developed by three sets of tangential water wheels located under the receiver and over the single tail-race; an arrangement like that at the Fresno plant. Each wheel has a double nozzle with deflecting hoods to turn the jets away from the wheel when the load decreases. The wheel shafts extend through the power-house wall and are coupled to the generator shafts. The generators are 360-kilowatt, 2-phase, inductor-type machines, delivering current at a periodicity of 8000 alternations per minute and a pressure of 2400 volts. The switchboard was equipped with hot-wire ammeters and static voltmeters. The pressure was increased to 16,700 volts for transmission by means of oil-insulated water-cooled transformers. A new high-tension double-break switch was introduced in this plant, and the outgoing wires were provided with three choke coils in series and a set of newly designed lightning arresters.

The transmission lines are 2-phase. They extend to Browns Valley, $7\frac{1}{4}$ miles, and to Marysville, $18\frac{3}{4}$ miles from the power house. The construction of these lines was not very different from the lines of the Nevada County plant. Triple-petticoat annealed-glass insulators were used and $\frac{1}{2}$-inch steel pins with porcelain bases.

This plant has been remodeled and is a part of the Bay Counties system of the California Gas and Electric Corporation.

SAN GABRIEL.

A 2000-horse-power plant was built on the San Gabriel River, near Azusa, in July, 1898, and power transmitted 23 miles to Los Angeles. The hydraulic system of this plant was designed to secure and utilize all of the available water supply, and it possesses some interesting features. The dam is submerged over 20 feet in the gravel bed of the stream, going down to bed rock to intercept the underground flow, which is all the water there is in the dry season. The means of conveying the water represents the most advanced practice of that time. The water way is nearly 6 miles long, is entirely covered, and is 66 per cent. tunnels, 28 per cent. redwood stave pipe and 5 per cent. concrete culvert. The balance consists of pipe curves and connecting pieces. Eight hundred feet head is utilized and four sets of tangential water wheels drive four 300-kilowatt, 2-phase generators, delivering current at 500 volts and 50 cycles. The transmission is at 16,500 volts, 3-phase, 23 miles to Los Angeles, over two circuits on a single-pole line. There is an auxiliary steam plant in Los Angeles, which is successfully run in parallel with the water-power plant. A great variety of electric service is supplied, and the switchboard system is one of the most elaborate in existence for an installation of no more than 3000 horse power. The system is being operated by the Pacific Light and Power Co.

SANTA ANA.

The Santa Ana plant has been in continuous operation since January, 1899. Water is taken from the Santa Ana River and from Bear Creek, and is conveyed through 18 tunnels and 16 flumes, having a capacity of 120 second feet, a distance of $2\frac{3}{4}$ miles to the penstock. Sand boxes and screens are provided for clearing the water; also an ingenious device for removing leaves from the flume.

The pressure pipe lines, two in number, are 30 inches in diameter and 2210 feet long, and are buried at an average depth of 7 feet,

Fig. 11. The Headworks, Intake Tunnel and Flume of the Mt. Whitney Plant.

Fig. 12. The Mt. Whitney Flume.

no other anchorage being deemed necessary. Gate valves in the two pipes and in the distributor make it possible to drain and inspect either pipe line without interfering with the operation of the plant. Laterals lead from the distributor to the single-jet deflecting nozzles under the floor of the building. The head of water utilized is 735 feet.

The power-house building is of concrete, long and narrow, and designed for eight generating units of 750-kilowatt capacity each. Each of the four units installed consists of a tangential water wheel and a 750-kilowatt, 3-phase, 50-cycle, 750-volt generator, mounted on the same base, with a single shaft supported by three bearings. These units run at 300 revolutions per minute, the speed being kept constant by means of Lombard type-F governors, the first governors of that type ever made.

There are three 30-kilowatt, 175-volt exciters driven at 1000 revolutions per minute by individual tangential wheels and governed by small sectoidal governors.

The station wires are laid in ducts under the floor leading to the marble switchboard and thence to the 250-kilowatt, air-blast transformers.

They step-up the pressure from 750 to 33,000 volts for transmission 83 miles to Los Angeles. The transformers are connected in star on the high-tension side with the neutral point grounded. A complete set of high-tension switches in duplicate is provided, and lightning arresters are installed. The 33,000-volt, 83-mile transmission to Los Angeles, was, when built, unequaled in length and voltage by any line in the world. It consists of two circuits of No. 1 medium hard-drawn copper wires arranged in isosceles triangles on a single-pole line and supported on 6-inch white glazed triple-petticoat porcelain insulators especially designed for this line and tested to 70,000 volts. The insulator pins have porcelain bases.

Each sub-station along the line is equipped with a set of horn type air-break pole switches, of original design. The 83-mile transmission is thus sectioned, with outdoor switches at the ends of each section. It is thus made possible to cut out a section of either circuit, for making repairs, without interrupting the service.

The telephone circuit is carried on the same poles, 5 feet below the power wires, on pony glass insulators. Both the power wires and the telephone wires are transposed and the service is entirely successful.

There are sub-stations on the 33,000-volt line at Redlands, Colton, Pomona, Puente, Shorb, Pasadena and Los Angeles. The 33,000-volt transmission line terminates at Los Angeles Station No.

1, where the Edison Company's original reserve steam plant of 2000 horse-power capacity is located. Here the transmission voltage is transformed to 2300 volts for general distribution and also for transmission to Station No. 2, in the heart of the business district. Station No. 2 is equipped with motor-generator sets for the delivery of 500-volt direct current, and also for the operation of a 220-volt, three-wire Edison system. The station also contains two storage batteries which are the largest west of Chicago. The first has 140 cells and a maximum discharge capacity of 2700 amperes, and a rating of 1100 amperes on a three-hour discharge. The second has 140 cells and a maximum discharge capacity of 3500 amperes, and a rating of 1300 amperes on a three-hour discharge. These batteries are used separately or combined, as desired. They float on the 220-volt system, and, in addition to carrying the peak load, prevent possible interruptions in the service due to short circuits on the transmission system.

Station No. 3, which has recently been placed in service, is a combination sub-station and steam auxiliary power plant, and in this latter respect is superseding Station No. 1. The sub-station is designed for four sets of double bus-bars for handling 60,000, 30,000, 15,000 and 2300 volts respectively, each set being on a separate floor. The 60,000-volt section will be the terminus of the 116-mile transmission from the new 30,000-horse-power hydro-electric plant now being built on the Kern River. The 33,000-volt line from the Santa Ana and Mill Creek plants now runs into the station, and the current is transformed to 15,000 volts for transmission to Station No. 2, and also to three new 2300-volt distributing sub-stations in the residence sections of the city. In addition to the sub-station apparatus there is a large steam generating plant and two 2000-kilowatt, 2300-volt, 3-phase, 50-cycle, steam turbo-alternator units. A new 30,000-volt line, carried on steel poles, connects Station No. 3 with a sub-station at Inglewood, where the current is transformed to 17,000 volts for the operation of the system of the United Electric Gas and Power Company, recently acquired by the Edison Electric Company.

MT. WHITNEY.

In June, 1899, the plant of the Mt. Whitney Power Company, on the Kaweah River, was put into operation. Water is diverted, as shown in Fig. 11, from the East Fork of the Kaweah River, and conveyed for nearly 5 miles in a wooden flume along the precipitous side of the cañon, shown in Fig. 12, to the forebay. Sand boxes and waste gates are provided at intervals.

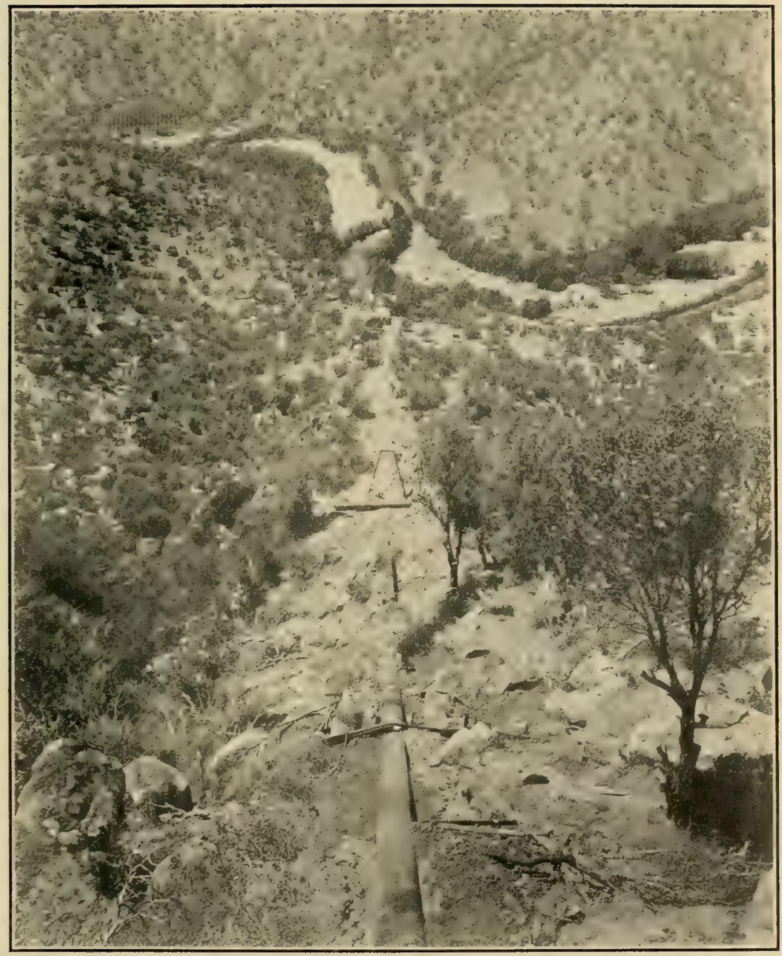


Fig. 13. The Pipe Line of the Mt. Whitney Plant, looking down to Power House.

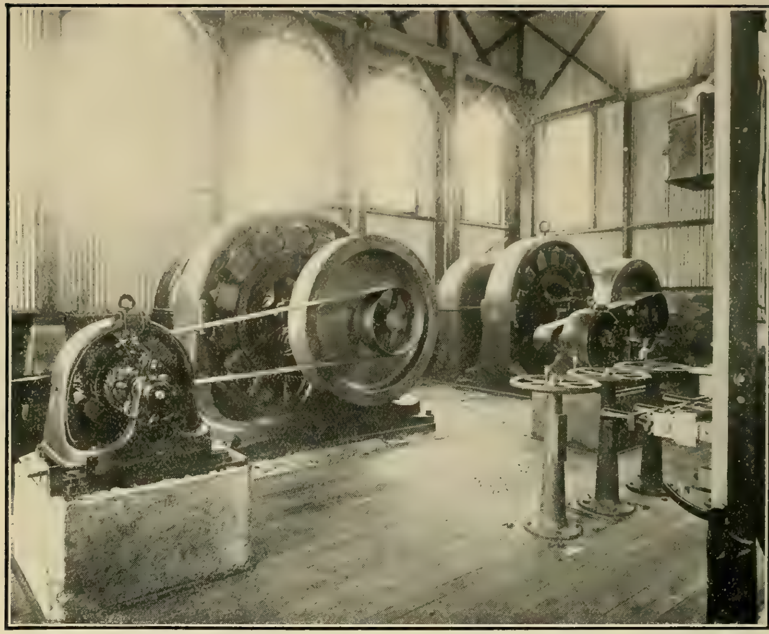


Fig. 14. Interior of the Mt. Whitney Power House, looking South-easterly.

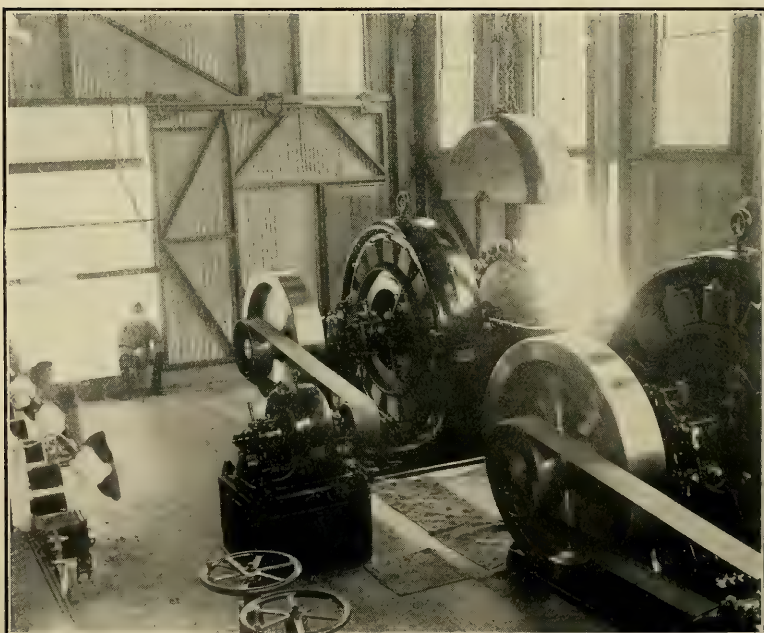


Fig. 15. Interior of the Mt. Whitney Power House, looking North-easterly.

The pressure pipe is 50 inches in diameter at the forebay, tapers to 24 inches in the first 50 feet, and to 20 inches in the remaining 3270 feet. It was laid without horizontal bends, as shown in Fig. 13, and is firmly anchored as well as buried in a trench. This pipe was provided with air valves, but the customary receiver at the bottom was omitted and the pipe terminated in branch castings of carefully designed internal diameter, so that the flow of the water should be gradually accelerated as it approached the nozzle tip. This design is now accepted as standard practice in hydraulics. The pressure at the power house is 565 pounds per square inch, corresponding to 1300 feet head, and the velocity of the water issuing from the nozzle is over 3 miles per minute. The interior of the power house, shown in Figs. 14 and 15, is noticeable for its compact, logical arrangement.

The generating units are like those installed in the Blue Lakes plant, having only two bearings, with the water wheel mounted on the extended end of the generator shaft overhanging one of the bearings, and a flywheel mounted on the other end of the shaft overhanging the other bearing.

The water wheels are of the tangential type, and were the first to be equipped with ellipsoidal buckets, Fig. 16. They are driven by a single jet of water at a speed of 514 revolutions per minute, and regulated by means of a hand-operated cut-off hood, Fig. 17, deflecting a part or all of the jet away from the water-wheel buckets, as may be required. The wear on the deflector shoe is shown in Fig. 18.

There are three 440-volt, 3-phase, 60-cycle generators rated at 450 kilowatts, and two 125-volt exciter units rated at 15 kilowatts, at 1050 revolutions per minute. The exciter units are belt-driven from pulleys on the flywheel ends of the generator shafts.

Cables are run in ducts under the floor to the marble switchboard, and thence to the 500-kilowatt, oil-insulated, air-cooled static transformers, which step-up the pressure from 440 to 17,300 volts for transmission. The high-tension wires pass through fused switches to the lightning arresters, which are in a separate building, and thence 41 miles to Tulare and 42 miles to Porterville. The single circuit transmission is 3-phase. Electric power is sold for operating pumps for irrigating, and has superseded steam and crude-oil engines.

This plant was completed in nine months from the time of beginning work.

In 1902, the transformers were moved from within the power house to a row of separate concrete cells outside, to guard against

possible accident. The flywheels also were removed from the generating units.

Some interesting studies on jets of water under high pressure, begun at the Blue Lakes plant, were further pursued at this plant. Figs. 19, 20 and 21 show, respectively, a jet at the Blue Lakes plant of 1897, a jet at the Mt. Whitney plant of 1899 and a jet at the Snoqualmie Falls plant, in Washington, installed in 1900.

In 1904, the Mt. Whitney Power Company built a second power house called Mt. Whitney No. 2, using water from the Middle Fork of the Kaweah River conducted through a ditch nearly 10 miles long to a 40-inch riveted steel pipe. A head of 360 feet is utilized to operate turbines driving 3-phase generators.

MILL CREEK NO. 2.

In 1898, the demands upon the original Redlands plant became so great that a second plant, known as Mill Creek No. 2, was built further up the cañon, and so located that water from its tail-race is taken directly into the intake of the first plant and used again to generate power.

This second plant was put in operation in September, 1899. It contained two 250-kilowatt revolving-field, 3-phase generators, driven at 375 revolutions per minute and delivering 50-cycle current at 11,500 volts pressure. At that time they were the highest voltage alternating current generators in use on the Pacific Coast.

The water way consists of 21 flumes, 6 tunnels and about 2¼ miles of concrete pipe.

Its capacity is 10 second feet at a grade of 0.2 of a foot per 100 feet. The concrete pipe is covered with from 2 to 3 feet of earth. At the end of the intake tunnel and first flume there is a large sand trap with five settling basins for clarifying the water. A fall of 627 feet is utilized in the pressure main, the water passing down through 1411 feet of 18-inch riveted steel pipe laid in a trench and buried. This pipe terminates in a steel Y-casting with three outlets, two large ones leading to the generating units, and one small one leading to the exciter units. The pipe is equipped with blow-offs and air valves, and has an air chamber located near the power house. Each branch of the pipe leads to a single deflecting nozzle. Each of the two generating units consisted of a 61-inch tangential water wheel direct-connected to a 250-kilowatt revolving-field, 3-phase generator, which delivered 50-cycle current at 11,500 volts directly to the line. Each was a three-bearing unit mounted on a single base. The two exciter units are 30-kilowatt two-bearing

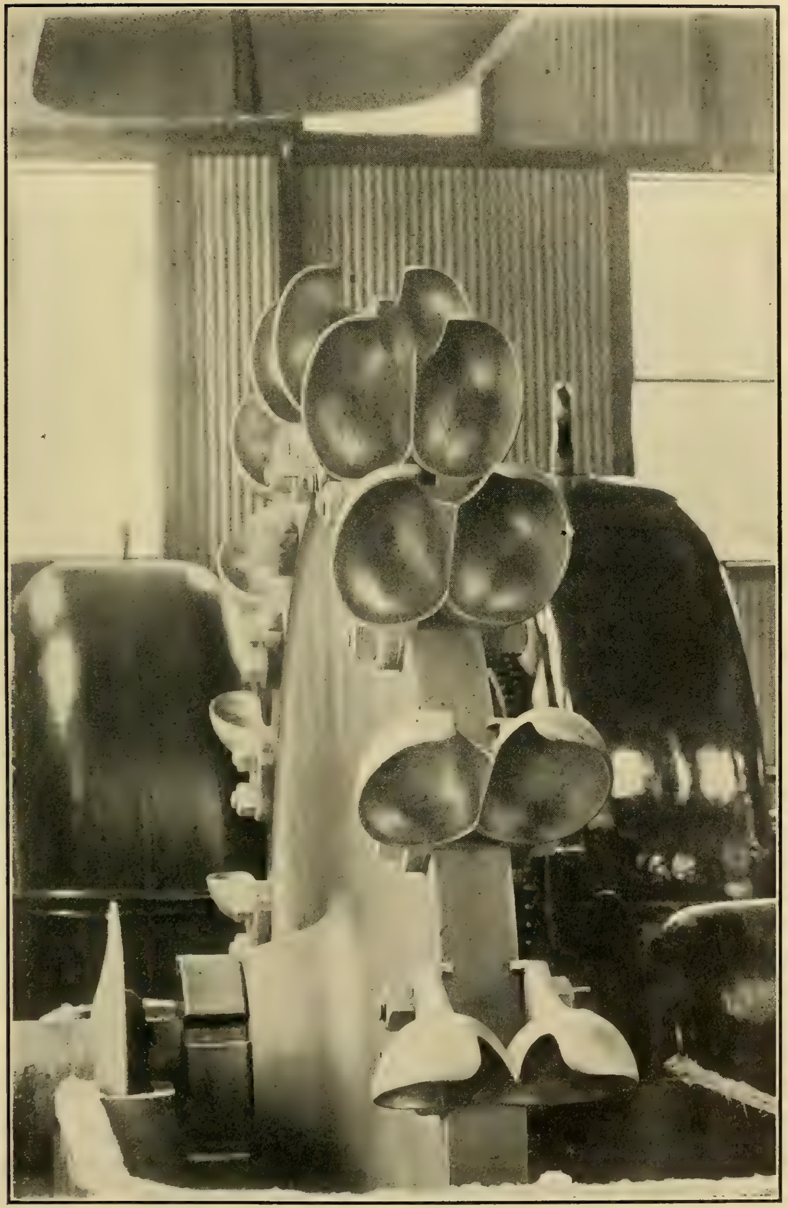


FIG. 16. THE ELLIPSOIDAL BUCKETS ON A 1000 H. P. WATER WHEEL AT THE MT. WHITNEY PLANT, AFTER MORE THAN A YEAR OF USE.

Fig. 17. The Stream Deflector at the Mt. Whitney Plant Deflecting 1000 H. P. into the Tail-Race.

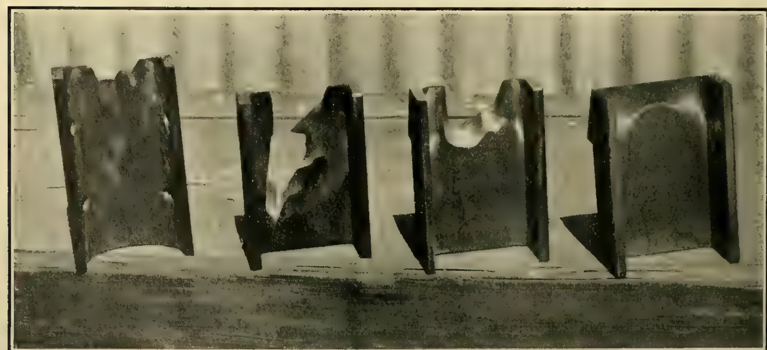


Fig. 18. Worm Deflector Shoes at the Mt. Whitney Power Plant.

units, the 22-inch tangential water wheels being overhung on the exciter shafts.

The transmission line joined that from the Redlands plant (Mill Creek No. 1), and extended thence to Riverside, a distance of about 23 miles. It is now connected to the 33,000-volt transmission to Los Angeles, operated by the Edison Electric Co. This plant was built with the idea of adding to it at a later date. The addition is now complete and is called Mill Creek No. 3, and is described later.

TRUCKEE RIVER.

In October, 1900, a 2000-horse-power plant on the Truckee River was completed. This plant uses 300 second feet of water, diverted from the Truckee River by a timber-crib dam, and conveyed in a canal 600 feet long and a pine flume 8600 feet long to a wooden penstock. Water flows to the wheels through two 72-inch redwood stave pipes 160 feet long. The maximum head is 84½ feet.

There are two pairs of 27-inch horizontal turbines. Each pair is rated at 1400 horse power at 400 revolutions per minute, and is direct-connected through a leather-link coupling to a 750-kilowatt, 3-phase, 500-volt generator. There are two 22½-kilowatt exciter units driven by individual turbines at 975 revolutions per minute.

The current is stepped-up from 500 volts to 22,000 volts by six 250-kilowatt, oil-insulated, air-cooled transformers, and is transmitted on a double 3-phase transmission line, 33 miles long, to Virginia City. This plant was built to supply power and light to the Comstock Mines and it has been very successful.

COLGATE.

One of the most widely known plants on the Pacific Coast is the Colgate plant, which was built in 1899, by the Yuba Electric Power Company, to provide means for meeting the demands made upon their Browns Valley plant. Colgate No. 1 was built on the north bank of the North Yuba River, at the Missouri Bar trail crossing. Five thousand horse power of electrical machinery was installed and current was transmitted to Sacramento. In June, 1900, the Yuba Electric Power Company and the Nevada County Electric Company were merged into the Bay Counties Power Company, and work was commenced on a large addition to Colgate No. 1 and a transmission 140 miles long to Oakland.

In the Colgate plant we have a demonstration of the economy of doing things on a large scale. The power house is an example of the long, narrow type with the generating units arranged along one side, as appears in Fig. 22, and a separate tail-race for each water wheel.

There are in the Colgate plant three 2000-kilowatt inductor-type generators, which were, when installed, the largest on the Pacific Coast. There are also three 900-kilowatt and one 750-kilowatt of the same type, making a total of 9450-kilowatts normal generator capacity. All the generators are direct-connected by leather-link couplings to their respective tangential water-wheel units.

The exciter unit consists of a direct-current generator, a tangential water wheel and a 3-phase induction motor, coupled together. The induction motor is connected to the low-tension bus-bars and normally floats on the system. Should the nozzle of the water wheel accidentally get clogged, the induction motor would take power from the bus-bars and keep the exciter going. This has occurred and so quietly as to be unnoticed by the station attendant. This excellent scheme has become standard practice.

There are eight transmission circuits radiating from the Colgate power house, carrying current at various voltages. One of the circuits crosses the American River with a span of 684 feet, the wires being arranged in a hexagon. The line most worthy of attention is the one reaching 140 miles to Oakland, and designed to carry 60,000 volts. This "Bay Line" has been operating at from 40,000 to 55,000 volts for the past 3 years, the voltage being raised as the load has increased, and will be further raised to 60,000 volts. It consists of two complete 3-wire, 3-phase circuits on separate pole lines 25 feet apart.

One circuit is of No. 00 medium hard-drawn copper, the other is No. 0000 7-strand aluminum cable. A porcelain insulator, 11 inches in diameter, was designed especially for this transmission. There are several interesting long spans at river crossings. The 125-foot masts at Vernon, where the line crosses the Sacramento River, are shown in Fig. 23. This span of No. 00 hard-drawn copper is 800 feet long and has a sag of 27 feet. Sticks of Oregon pine, 20 feet long, were inserted in the guy lines for insulation.

The most remarkable feature of the "Bay Line" is the spanning of Carquinez Straits, Fig. 24. The length of this span, the longest in the world, is 4227 feet, and current is carried on three of the four $\frac{7}{8}$-inch stranded steel cables, one being kept as a spare. The cables are anchored at each end in heavy concrete blocks. They rest in

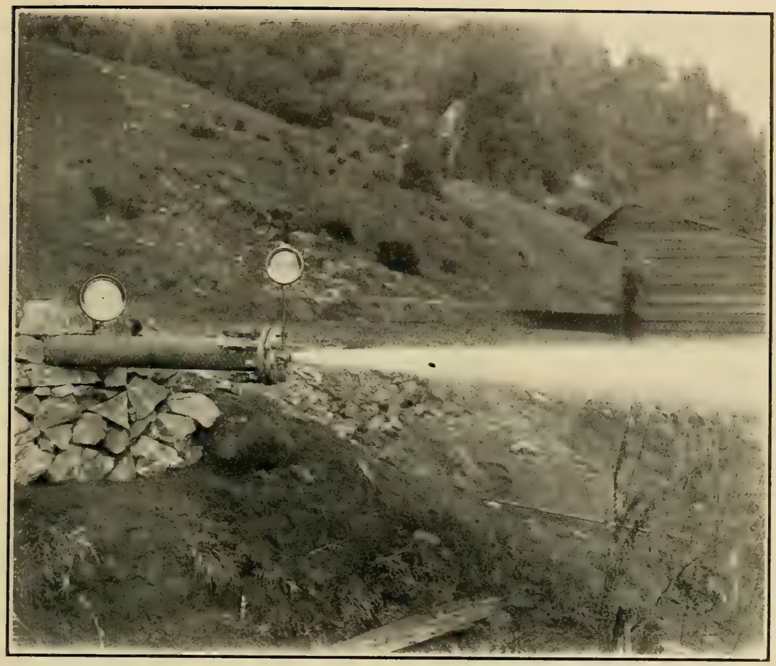


FIG. 19. A JET AT THE BLUE LAKES PLANT OF 1897.

FIG. 20. A JET OF WATER AT THE MT. WHITNEY POWER PLANT—1899.

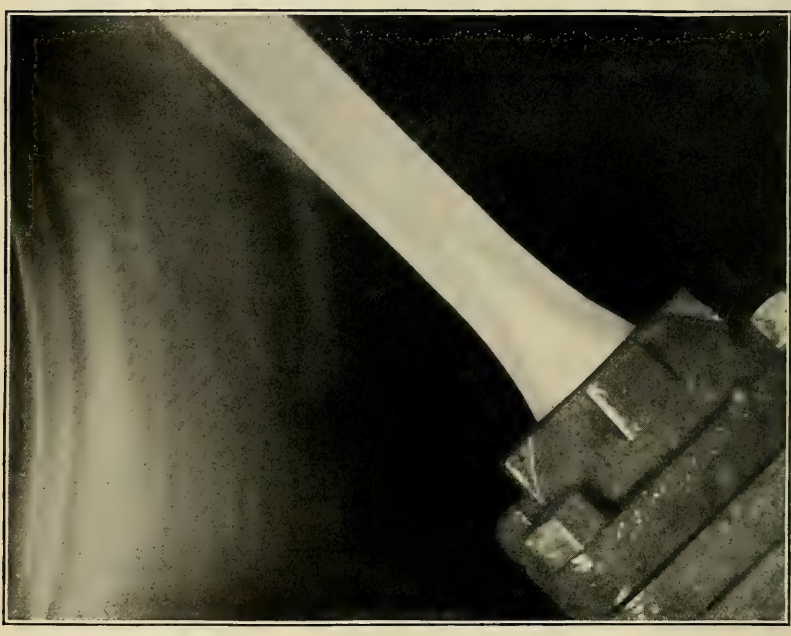


Fig. 21. Jet From the Needle Nozzle at the Snoqualmie Falls Power Plant, Washington, in 1900.

grooved lignum-vitæ rollers supported in a row on regular line insulators, and are supported on special steel towers.

The pull on each cable at its anchorage is about 12 tons, and special strain insulators were designed to hold the cable and insulate it at the same time.

The two transmission circuits are joined at the north tower of the Carquinez span and separated again on the southerly shore. The two transmission circuits are carried on a single line of 60-foot square poles through Oakland to the sub-station at Piedmont. This sub-station is connected to the Grove Street sub-station, which is the terminus in Oakland of another long-distance transmission line reaching from the Standard Electric power house at Electra to Oakland, San Jose and San Francisco.

VOLTA.

In November, 1901, the 3000-horse-power plant of the Northern California Power Co., at Volta, Shasta County, was put into operation. Water is gathered from Galpin Creek, Berry Creek and Battle Creek, and conveyed through ditches to Mill Creek, from which it is diverted and then conveyed through 3400 feet of ditch to a reservoir at the head of the pipe line. This reservoir stores enough water to carry the full load of the station for about 6 hours.

The pressure pipe consists of 800 feet of wood stave pipe and 6000 feet of steel pipe, part riveted and part lap welded. The pipe terminates in a 30-inch, lap-welded steel distributor with cast-steel fittings, and is equipped with six automatic air relief valves suitably housed to prevent freezing in winter.

The power house contains three 750-kilowatt hydro-electric units, each consisting of a tangential water wheel driven at 400 revolutions per minute by a single jet of water under 1204 feet head, connected by means of a leather-link coupling to a 500-volt, 3-phase, 60-cycle generator. The speed of these units is regulated by means of Lombard type-F governors, which deflect the nozzles. There are two 22½-kilowatt exciters, driven at 975 revolutions per minute by means of water under 400 feet head, brought to the power house from a spring through an entirely independent pipe line and hydraulic development.

The transformers are separated, by a fire wall, from the generators, and stand on a floor depressed below the level of the generator floor. There are three sets and one spare. They are rated at 350 kilowatts each, are oil-insulated, air-cooled, and raise the pres-

sure to 22,000 volts for transmission. The high-tension taps are delta-connected.

The transmission line consists of two 3-phase circuits of No. 4 B. & S. gage bare copper wire on a single-pole line. The insulators are of glass and are supported on eucalyptus wood pins treated with linseed oil. The extreme length of the original transmission was 99 miles.

Electricity is supplied to the copper mines near Keswick and to more than a dozen inland towns within a radius of 100 miles from the power house.

The company has built another power house 20 miles north of Volta to utilize the waters of Cow Creek under 1196 feet head, for developing about 4000 horse power. This power house was completed in the latter part of 1903. From it two 3-phase circuits run to Bully Hill, where they connect with the line from the Volta power house, while a single circuit runs down the Pitt River to Kennett, and thence to Keswick, where it also connects with the line from Volta.

ELECTRA.

The plant built on the Mokelumne River, at Electra, by the Standard Electric Company, is one of the largest and most expensive plants on the Pacific Coast. The builders took so much pains to have everything of the very best that it is difficult to say just when the plant was finished. Water is taken from the Blue Lakes water system and is conveyed through two 30-inch pressure pipes down to the power house, where a head of 1467 feet is obtained. This is slightly more than is used at the San Joaquin plant.

The power house is a steel frame structure, covered with galvanized iron. The pressure pipe lies along one side of the power house and has 45° branches leading under the floor to the water wheels. The individual tail-races continue in the same direction to the other side of the power house and join at 45° a common tail-race leading to the river.

The generator room, shown in Fig. 25, contains five 2000-kilowatt, 3-phase, 60-cycle, 2200-volt, inductor-type generators, each driven through a leather-link coupling at 240 revolutions per minute, by a pair of tangential water wheels mounted within one housing. Cables are laid in a subway, extending the length of the generator room, to the switchboard gallery at one end. The two exciter units are located in an alcove. Each is driven by a tangential water wheel, and also is direct-connected to an induction motor. From the switchboard the current is conducted to the step-up transformers,

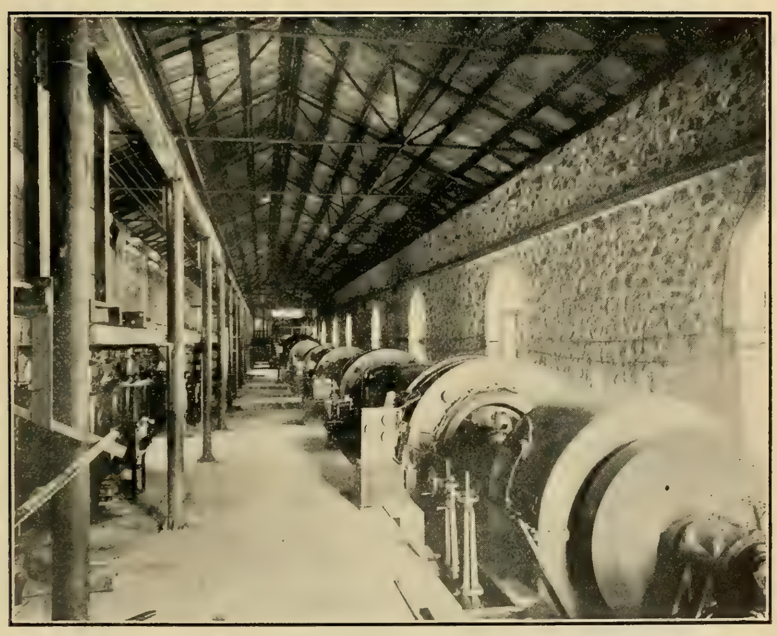


Fig. 22. Interior of the Colgate Plant.

Fig. 23. Masts 125 Feet High for the 800-foot Span Across the Sacramento River at Verona.

located in a separate room, where the pressure is raised from 2200 to 55,000 volts for transmission.

The transmission line, consisting of three $\frac{7}{8}$-inch, 37-strand aluminum cables supported on special high-tension insulators, extending from the power house 154 miles to San Francisco, is one of the most interesting in the State.

It was designed for a potential of 60,000 volts and has been in use for the last 2 years, delivering current at pressures ranging from 30,000 to 55,000 volts; the pressure being raised with the increasing sales of current.

This is the only long-distance transmission that has reached San Francisco, the largest market for power and light in the State. The most notable feature of the transmission is the San Joaquin River crossing, shown in Fig. 26. The aluminum cables are supported on four rectangular steel towers, 150 feet high and resting on piles. The longest span is 618 feet. Since the absorption of the Standard Electric Company by the California Gas and Electric Corporation, the plant at Electra has been running in parallel with the other plants of the corporation's system and the line has been connected in with the 140-mile Colgate-Oakland transmission, known as the "Bay Counties" line.

LITTLE BEAR RIVER POWER HOUSE, NEAR ALTA.

This plant went into operation in November, 1902. It utilizes a fall of 660 feet in the main Placer County ditch of the South Yuba Water Company. An abandoned reservoir was repaired, and is used to store 2,160,000 cubic feet of water at the head of the pipe line.

The pressure pipe is 5380 feet long, of flange-steel plates, hot riveted throughout. It tapers in diameter from 38 inches at the top to 36 inches at the bottom, and varies in thickness from $\frac{3}{16}$ inch at the top to $\frac{3}{8}$ inch at the bottom. The pipe is provided at the bottom with a 37-inch outside screw gate valve, and terminates outside the power house in a 48-inch riveted-steel distributor. Curved laterals lead the water to the turbines.

There are two hydro-electric units installed at present. These consist of a high head turbine direct-connected to a 1000-kilowatt revolving-field, 500-volt, 3-phase generator. They run at 400 revolutions per minute. Cables are laid in glazed-tile pipe under the cement floor, and lead from the generators to the switchboard and thence to the transformers.

The transformers are 375-kilowatt, oil-insulated, air-cooled

type and, being delta-connected, raise the voltage to 16,000 for transmission 61 miles to Sacramento.

This plant runs in parallel with the two others built by the same company, one at Newcastle and the other at Auburn.

The property of the South Yuba Water Company and that of the Central California Electric Company has been acquired by the California Gas and Electric Corporation.

ONTARIO.

The 1500-horse-power plant of the Ontario Power Company was put into operation in December, 1902. The waters of the San Antonio River are conducted through a 30-inch cement-pipe conduit to a cement forebay 694 feet above the power house. There are four inverted siphons of riveted steel pipe in the gravity water way and the cement pipe passes through ten tunnels, the longest of which is 560 feet x 5 feet x 6 feet.

The pressure pipe is 24-inch riveted steel pipe at the forebay and 20-inch lap-welded tubing at the lower end where it joins a steel distributor, from which three 12-inch pipes lead to the water-wheel nozzles. Each pipe is fitted with a slow-motion valve with by-pass and each water wheel has a separate tail-race.

The power house is of granite, 60 x 30 feet, with a galvanized iron roof on steel trusses.

The hydro-electric generating units, shown in Fig 27, are of recent design. Each consists of a tangential water wheel, with ellipsoidal buckets, mounted on the same shaft with a 250-kilowatt generator and provided with a single needle regulating deflecting nozzle. There are three bearings and a single base-plate. The unit makes 375 revolutions per minute under an effective head of 687 feet, and delivers 3-phase current at 50 cycles and 1150 volts.

The principal transmission of power is to Ontario, at the generator pressure. The surplus power is sold to the San Gabriel Electric Company, and transformers are provided for stepping the pressure up to 16,000 volts for their use.

Power is principally used to drive irrigating pumps and for lights in the vicinity of Ontario.

MILL CREEK NO. 3.

Early in 1903, the Edison Electric Company, of Los Angeles, completed a noteworthy plant, known as Mill Creek No. 3. This is an addition to Mill Creek No. 2, so far as the power house is concerned; otherwise it is distinct. Water is taken from Mill Creek

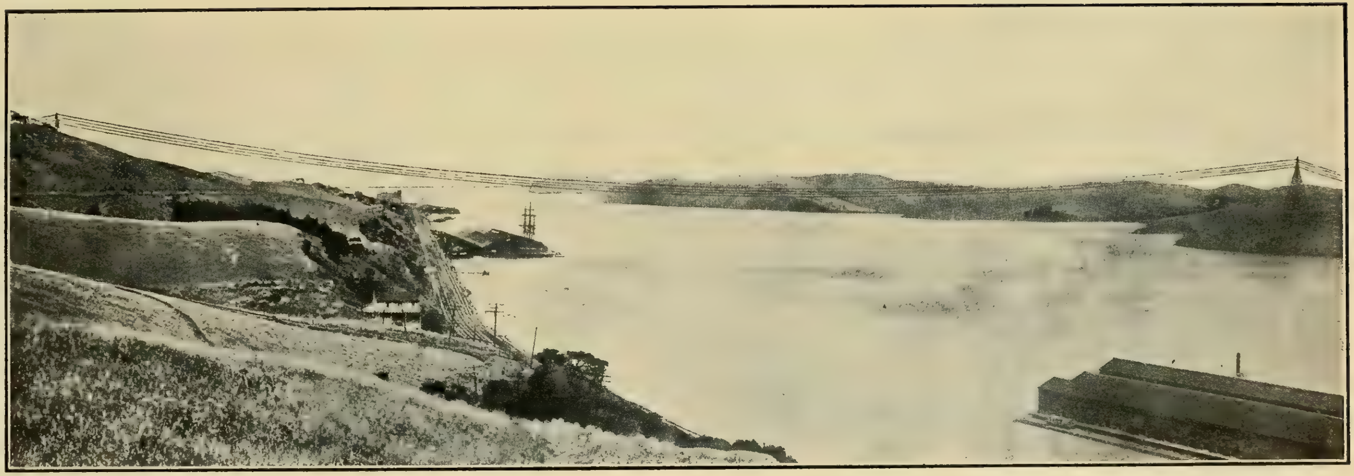


Fig. 24. The Carquinez Span—4227 Feet Between Supports.

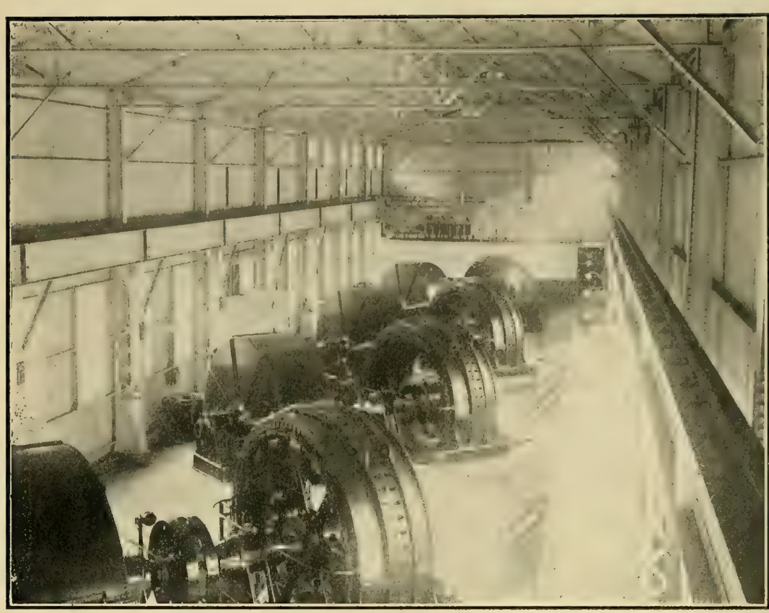


Fig. 25. Interior of the Electra Power House.

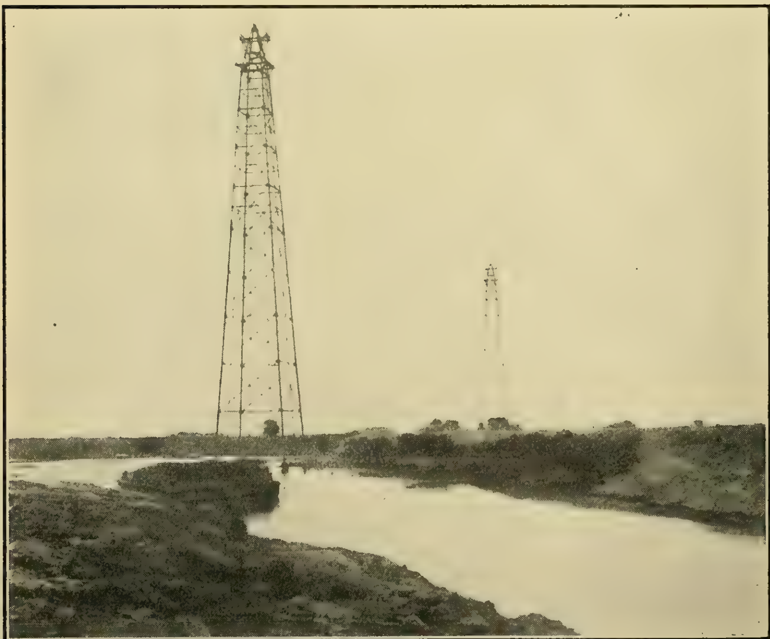


Fig. 26. The San Joaquin River Crossing.

above the intake of plant No. 2, and is conducted through a covered water way to the forebay. This water way has five inverted siphons, the longest of which is 2150 feet. There are 25,000 feet of concrete pipe, 31 inches inside diameter and 3 inches thick. There are nineteen tunnels, 4 feet wide by 6 feet high and ranging in length from 112 feet to 1067 feet.

At the forebay is a series of settling basins to clarify the water. The pressure pipe is 26 and 24 inches in diameter, and terminates at the bottom in branches leading to the nozzles. The head utilized is 1960 feet, which is higher than any other electric power plant now operating in this country.

The water passes through needle regulating deflecting nozzles to the water wheels.

The walls of the power house are of concrete, the roof is of corrugated iron on steel trusses and has an anti-condensation lining.

Each large unit consists of a tangential water wheel and a 750-kilowatt, 50-cycle, 3-phase, 750-volt generator, with a single shaft supported by three bearings on a single bed-plate. Fig. 28 shows one of the water wheels after more than a year's service.

The transformers in this plant raise the pressure from 750 to 33,000 volts for transmission to Los Angeles, and are the first 3-phase transformers of large size installed on the Pacific Coast.

DE SABLA.

Some of the most advanced ideas in hydro-electric power plant practice are embodied in the de Sabla plant, on Butte Creek, which the Valley Counties Power Company began operating in October, 1903.

Water from Big Butte Creek is conveyed about 10 miles in a ditch and discharged into a regulating reservoir, which is at an elevation of 1560 feet above the power house. From this reservoir, two 30-inch steel pressure pipe lines conduct the water 6000 feet down to the power house.

The first pipe line terminates in two branches leading to the 2000-kilowatt units, which went into operation in October, 1903, and the second line terminates in the nozzle of the 5000-kilowatt unit, which went into operation in September, 1904.

A new form of hydraulically operated piston gate valve was installed in each of the branch pipes. Their construction is such that when full open there is an unobstructed passageway of uniform diameter, so the hydraulic losses in this gate are reduced to nothing more than the friction of an equal length of straight pipe.

They are operated by pressure water from the pipe line, and the manner of admitting it to the operating piston is such that too rapid closing or opening of the valve is an impossibility.

The 2000-kilowatt generators are like those installed in the Colgate power house, and each is driven at a speed of 240 revolutions per minute by a tangential ellipsoidal water wheel of 3700 horse power, mounted on the extended end of the generator shaft and overhanging one bearing. Each complete hydro-electric unit has two bearings only.

The 5000-kilowatt generating unit shown in Fig. 29 represents the highest type in use at present.

It delivers 3-phase, 60-cycle current at a pressure of 2400 volts and is driven at 400 revolutions per minute by a Doble tangential water wheel. This is the most powerful single water wheel yet constructed, and it is capable of delivering 8000 horse power from the single jet of water, 6 inches in diameter, which issues from the needle regulating deflecting nozzle at a velocity of approximately 20,000 feet per minute, and impinges upon the steel buckets of the water wheel.

The general design of this remarkable unit is shown in Fig. 30.

It is a two-bearing revolving-field type, the water wheel being mounted on the extended end of the shaft and overhanging the bearing. The shaft is of fluid-compressed, hydraulic-forged, $3\frac{1}{2}$ per cent. nickel steel, oil-tempered and annealed, with an axial hole. It is 20 inches in diameter in the middle portion and 16 inches in the bearings, which are 60 inches long, ring-oiling, and water-cooled. The rubbing speed in these bearings is higher than has been used heretofore. The water wheel consists of a rolled steel disk, machine-finished all over, fastened to the end of the shaft in an original and superior manner and having cast-steel ellipsoidal buckets securely bolted to its periphery. Every bucket is accurately fitted to the disk and all hydraulic surfaces are ground smooth and true, and the wheel is carefully balanced, both statically and dynamically. The nozzle is of the needle regulating deflecting type, moved by a vertical water-wheel governor. This unit has, in actual service, been delivering from 5000 to 5500 kilowatts almost continuously since September, 1904.

The exciter set consists of a direct-current generator, an induction motor and a tangential water wheel, all on the same shaft; supported by three bearings on a single bed-plate.

Current from the generators passes the marble switchboard and, at present, is raised from generator pressure to 55,000 volts for transmission. A new type of 4-break, 60,000-volt oil switch has been installed in this plant, each switch being located in a separate

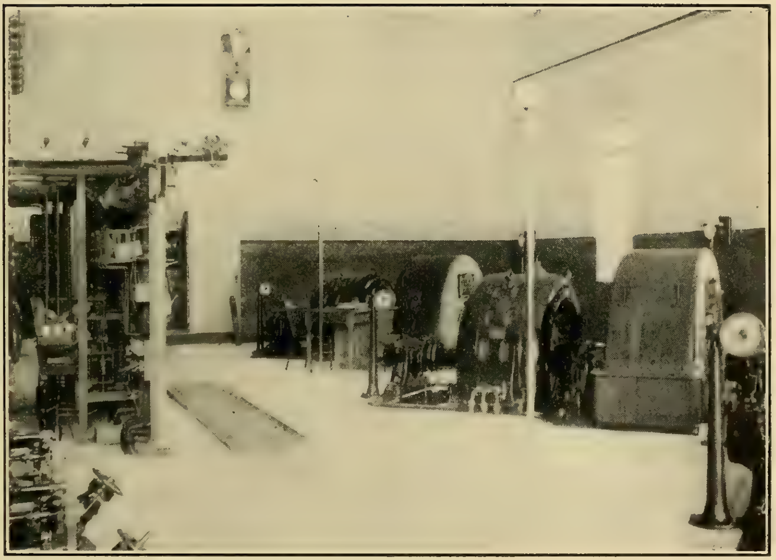


Fig. 27. Interior of the Ontario Power Company Plant.

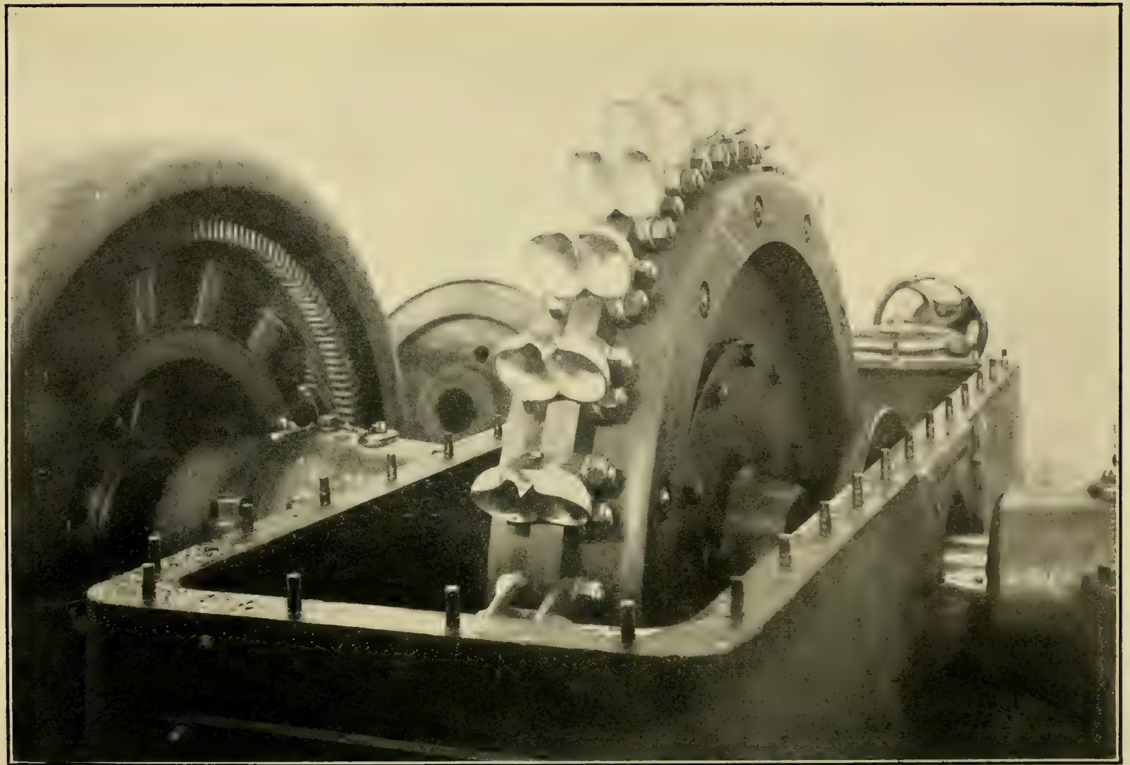


FIG. 28. WATER WHEEL IN MILL CREEK NO. 3 AFTER MORE THAN A YEAR OF CONTINUOUS SERVICE UNDER 1960 FEET HEAD.

fireproof compartment, and each set of three switches being mechanically connected so that they are opened or closed simultaneously.

Current from this plant has been delivered in Calaveras County, over the lines of the California Gas and Electric Corporation, a distance of 378 miles from the power house. This is the record, at present, for long-distance transmission.

AMERICAN RIVER.

One of the most recent plants, located on the American River, utilizes a head of 575 feet, and develops 3000 kilowatts. About 7 miles of open gravity water way has been constructed to convey 158 second feet of water to the penstock. Two 36-inch pressure pipes lead down to the power house and terminate in branches leading to the nozzles of the tangential water wheels. The power house is of concrete with steel roof trusses and a slate roof.

The hydro-electric generating units are of the two-bearing type with a tangential water wheel at each end of the shaft. Hollow nickel-steel forged shafts are used. Three-phase current is delivered at 2200 volts, 60 cycles, and is transformed to 30,000, 40,000 50,000 or 60,000 volts for transmission, depending upon the connections. The transformers are 625 kilowatts each, oil-insulated, water-cooled, and are located in a sparate fireproof building. A set of horn-type air-break switches are located in each of the two main transmission lines which lead from the power house, one to Folsom and the other to Stockton.

The transmission conductors are 7-stranded aluminum cables, equivalent in carrying capacity to No. 1 B. & S. gage copper wire. Power is delivered to numerous mines along the line of the transmission, and in Folsom and Stockton.

CONCLUSION.

Mention might be made of a number of smaller plants that have been installed at various places throughout the State, but the art of bringing to market the power of California mountain streams is fully set forth in the plants described.

The art has grown from the rough engineering period, as instanced in many of the pioneer plants, to a high plane, representing the very best in design and construction.

In the early days the tendency in hydraulic work pertaining to electrical generation was to follow other lines of engineering older established. For instance, the idea of a receiver, or distributor, larger in diameter than the pipe, and which has since been discarded

in the well-designed plants, was taken directly from steam engineering practice.

The tendency is toward larger plants, with larger generating units; higher hydraulic pressures and more expensive and reliable water conduits, tunnels preferred; longer transmission lines and higher voltages, with more expensive and reliable line construction and insulators.

Up to the present time, the transmission line has proved to be the weakest link in the chain of continuous and uniform service, and to this feature it is essential that much more attention shall be given by transmission companies.

The undeveloped water powers of the State which can be made available for commercial transmission far exceed in energy all the powers now utilized, and as the market for power is rapidly increasing and the business is a profitable one, we predict that many more plants will be constructed in the near future.

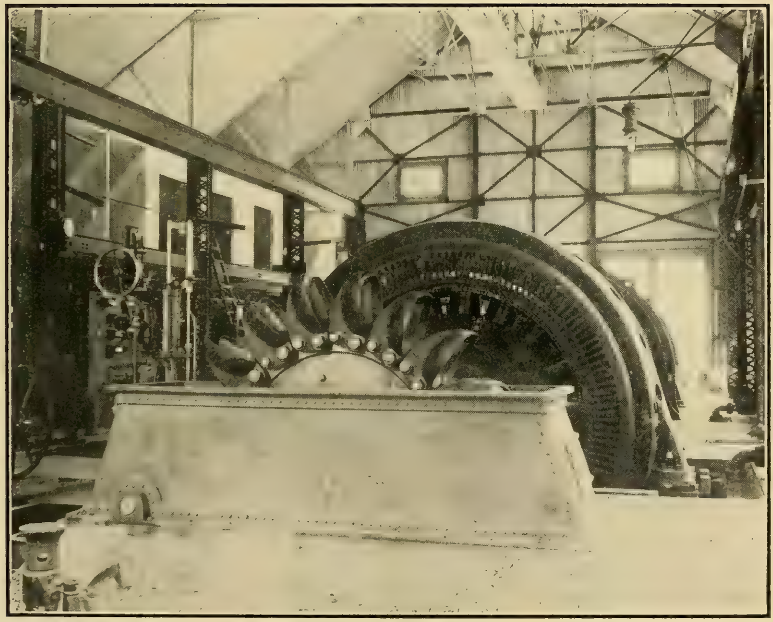


FIG. 29. 8000 H. P. HYDRO-ELECTRIC GENERATING UNIT IN THE DE SABLA POWER HOUSE.

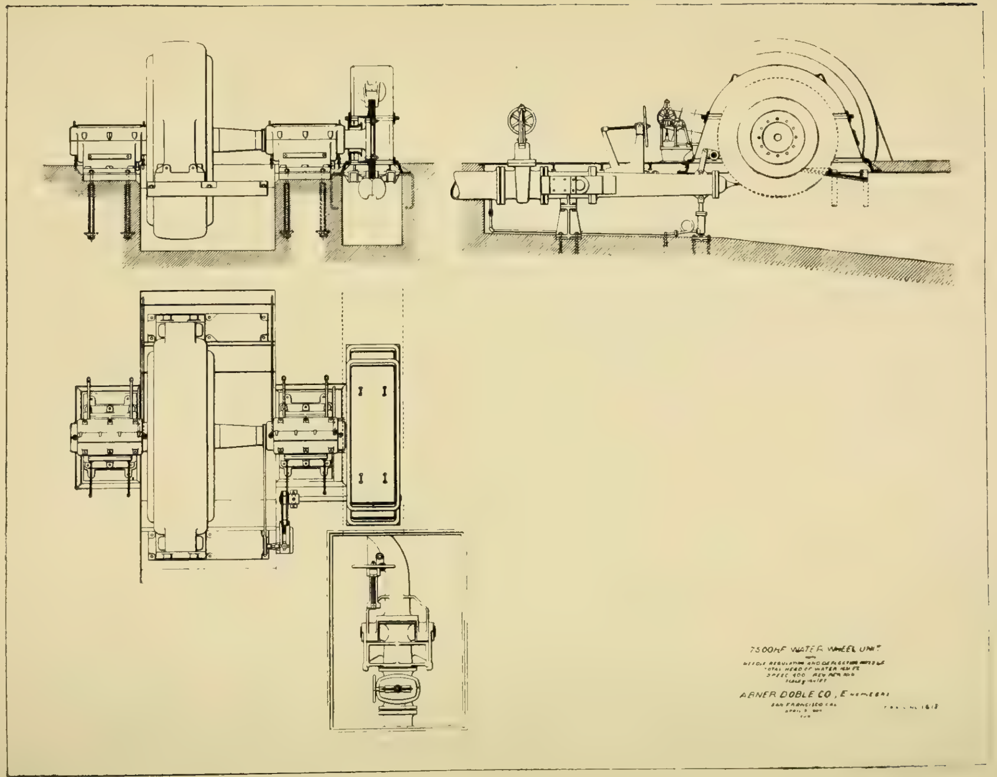


Fig. 30. Outline of the 5000-Kilowatt Hydro-Electric Generating Unit in the de Sabla Power House.

WEAK POINTS IN LONG-DISTANCE ELECTRIC TRANSMISSION.

By James C. Bennett, Member of the Technical Society of the Pacific Coast.

[Read before the Autumnal Meeting of the Society, December 2, 1904.*]

In the excellent papers to which we have been listening we have been shown, quite conclusively, the many advantages of transmitting electrical energy, generated at isolated stations, over long distances and at high pressures. There have also been pointed out some of the points in which we may expect improvements, which we sincerely trust will not be long forthcoming. It may not be amiss, at this time, however, to emphasize some of these weak points by noticing their effects. Unfortunately, I have been unable to acquaint myself with the conditions of other services than that of which I shall speak, hence, my statements cannot be so broad as I should wish them to be; but, as the service to be considered is a continuous one for the twenty-four hours of every day in the year, I think that there have been very good opportunities for developing some of the weakness of long-distance transmission.

The requirements to which I shall refer are those appertaining to lead smelting. For the sake of better understanding the conditions to be met, I shall outline the nature of such a service. There are some motors used for running shop tools, crushing machinery, etc., and required for but ten or twelve hours per day, which applications, being quite commonplace, require no further mention at this time.

Next to these in importance are the installations for driving the mechanical roasting furnaces. These furnaces, be it understood, are in operation continuously, night and day, and the ore contents are treated at such a degree of heat that they are almost and in some instances quite sticky. It must be evident that, under such conditions, it is very necessary that the operation be continuous, as, by stopping the furnace, the loss due to the falling of temperature to that of the atmosphere and its being again raised to the working heat becomes an important item; and, if the ore requires to be carried at a sintering or sticky heat, there is still further loss in breaking up, by hand, the agglomerated bed of ore. Thus, we can readily see the necessity of a continuous supply of power for such service.

* Manuscript received February 13, 1905.—Secretary, Ass'n of Eng. Socs.

The darkness, incident to stoppage of current at night, is also of more significance than the simple fact that it becomes suddenly dark, as will be more clearly shown when the other requirements are outlined.

The most imperative demand for continuous current, however, is that of the blowers which supply air to the blast furnaces. In this service, it is absolutely necessary that the pressure of the blast be always kept from falling to zero. Should it be allowed to do so, either of two things is likely to result. In the event of a momentary stoppage, as for a few seconds or a minute, there is great danger of an explosion, due to the fact that, when the pressure is removed, the combustible gases of the blast furnace at once extend backward into the blast pipe, as this has become the direction of least resistance; and, when the pressure is again applied, there is formed a violently explosive mechanical mixture of air and furnace gases, which, on coming in contact with the molten contents of the furnace at the tuyeres, ignites, and the resulting explosion naturally runs back toward the blower as being the most prolific source of oxygen. The result of the explosion is a damaged blast pipe or blower, or both, beside the danger of injuries to workmen. On the other hand, should the pressure unexpectedly drop to and remain at zero, or even but a few ounces below the normal pressure, for a considerable length of time—say eight or ten hours or more—the molten contents of the furnace will freeze, that is, will cool and solidify, thereby forming a practically solid column of rock, which means that the furnace must be taken apart and the "charge" picked and broken out by hand—an operation requiring probably a week or more of work of the most laborious nature.

From this sketch will be seen the reasons for so strongly insisting on a thoroughly reliable supply of power. It is not really to be wondered at that this necessity is not fully appreciated by those who are engaged in furnishing the power, for, while some of their representatives frequently call on their various customers, it is probable that, by reason of the seeming natural perversity of things, they have very seldom, if ever, been on the ground at the moment of interruption, and they thus have had little or no opportunity to come to a full realization of the importance of the matter in the eyes of the consumer.

Again, referring to the illustration in question, let us notice the effect, in the blower room, of an interruption of current. Fortunately, for economy's sake, it is necessary to keep steam up to working pressure at all times, regardless of the possibility of shutdowns of electric current, to meet the demands of heating, etc.;

hence the expense of keeping up steam pressure is not in this case directly chargeable to the unreliability of the current. However, in view of the shut-downs which occur from time to time, it is seen to be necessary to be prepared for them. On taking up the question of electrically driving the blowers, there are two principal points presented for solution. The one is, as just mentioned, that of insuring against a sudden total absence of pressure in the blast pipe; the other is that of occasionally changing the blast pressure or, synonymously, the speed of the blower.

The first problem is solved very safely by installing a small auxiliary blower, driven by a direct-connected steam engine. This blower has only sufficient capacity to maintain a pressure of say one or two ounces per square inch—in short, enough to prevent a backward flow of the furnace gases, should the main blower suddenly stop. This unit is run continuously, day and night, usually at slow speed, and, in case of an unexpected stoppage, is speeded up to its full capacity until a large reserve steam unit can be got in operation. Owing to the uncertainty as to the moment at which the current may cease, it becomes necessary to keep the engine of this large unit constantly warm by means of steam supplied through a small by-pass from the main steam line, as it is of such size that, were it necessary to heat it up at each call, there would be a great delay just at the time when every moment is of the most vital importance.

A prominent characteristic of the many stoppages of current is the time of their occurrence. On referring to records, it is to be observed that by far the greater number take place at night. Mechanically, this should not be so; from which I incline to the belief that its principal cause must be one that renders its occurrence well-nigh unavoidable, viz, that men do not maintain their highest standard of ability and reliability at night as during the daytime. Night is, of course, as we all know, not a natural time for man to be expected to be fully up to his highest standard of mental activity, hence the reason for describing the cause as "well-nigh unavoidable."

Coincident with these nocturnal stoppages is the sudden plunging of the entire plant into utter darkness, for it is almost certain to receive its lighting energy from the same source as its power, hence the lights must simultaneously suffer the same experience as the motors.

Picture to yourselves, if possible, the conditions existing in a large station of a city fire department at the time of a midnight alarm and imagine the effect if all the lights in the building were extinguished just as the alarm sounded, leaving but one or two oil lanterns burning in lieu of the many brilliant lights so suddenly

darkened, and you will have before you a picture partially portraying the conditions existing in a smelter's blower room at the time of a night stoppage of current. There are four things which require to be done immediately—I might well say instantly—and in exactly the order named. Close the blast gate on the blower just stopping, speed up the auxiliary blower, get the reserve steam-driven blower under way, and open its blast gate. The matter of closing and opening the blast gates may not, to the casual listener, be taken as a task of any magnitude; but I would ask you to consider that the blower gates are from 24 to 36 inches in diameter, and that it taxes severely the strength of one man to operate one of these gates. I mention that these operations must be performed in a certain order, to show another place where the confusion, incident to the sudden darkness, may lead to serious consequences, as changing the order of their execution is likely to produce the same result that has been attributed to sudden drop of pressure.

The only advantage which a daytime stoppage has over one at night, is its absence of the sudden darkness, for day or night the operation is the same; and, as almost every blower room that I have visited shows the result of growth by its crowded conditions, the difficulties attendant upon rapid movements about the floor are necessarily increased by reason of being obliged to follow indirect paths from one point to another, hence another possibility of confusion among the workmen, even though they may be quite familiar with the locations of the various machines.

I mentioned, a moment ago, that there are two problems presented for solution in considering an electrical installation for the purpose of driving the blowers. The first I have just dwelt upon; the second is of interest, probably, mechanically rather than in the light of the present consideration. It may, however, be worthy of mention here. The requisite blast pressure varies, from time to time, over a rather wide range—some ten to fifteen ounces per square inch—and it is, therefore, necessary to provide for changing the speed of the blower. As the variable-speed induction motor, owing to the wide differences between its various speeds, is not well suited to the case in question, it becomes necessary to find other means, which has been done by providing the regular constant-speed induction motor with a number of pulleys, of diameters varying by one or two inches, and fitted to the motor shaft with feather-way and set-screw. Thus they can be slipped on or off the motor with comparative ease and with considerable rapidity, the difference in the length of belt being taken up by means of an extra-long sliding base. The small auxiliary steam-driven blower is then used

to carry the slight variations of pressure, and, when they become too great to be easily taken care of by the small unit, the motor pulley is changed.

Having dwelt at some length on the difficulties encountered by the consumer of electric power, who must have a continuous supply of current throughout the entire twenty-four hours of the day, I would say a word or two of the points upon which improvements could still be made, and where it is extremely desirable that they should be. From what has been said of the effects of even momentary stoppages of current, it must be evident that the claim of the producers that they can switch from one line to another, in the event of a break-down on the first one, in about one minute's time, is not sufficient to give really satisfactory service to such customers as have just been described; for the one minute, necessary to make the change, is so long a time that the motors running have ample opportunity to drop in speed to such a rate that, when the power is again supplied, it can hardly fail to either blow their fuses or burn them internally. Hence, the effect is no better that when there is a "short" of the same duration. If notice be given beforehand of an approaching shutting off of the current, the result is not quite so aggravating, as the men in charge of the various motors about the plant can be warned to watch for a stoppage, and so, as soon as it occurs, they can throw out their switches and thus protect the motors; but when there is a "short" it is almost safe to say that the fuses on every motor on the plant will require to be replaced. The thought occurrs to me that some of my hearers may be inclined to believe that the exacting requirements of smelter service have been somewhat exaggerated, but in support of my statements I would say that many years of experience have conclusively proved the absolute necessity of having all vital parts of the power plant in duplicate. Consequently, in visiting any smelting plant, of even moderate size, it will be at once seen that boilers, pipes—both steam and water—engines, pumps, blowers, etc., are all so arranged that, in case of accident of any kind, the reserve can be at once placed in commission. It is no uncommon thing for a smelter to run for ten or fifteen years without at any time entirely closing down the power plant.

There are, then, two principal points, the importance of which I would urge upon the electrical engineers. The one is that the power, even with previous notification, should never be shut off for trivial repairs; when such things come to your attention, make every possible effort to conserve them so that, when a shut-down is made, there may be a number of these small matters attended to

at the one time. The second is the necessity of developing a means of switching from one line to another instantaneously—in the strictest sense of the word.

DISCUSSION.

MR. R. W. MYERS.—Mr. Bennett's paper shows the importance of transmitting electrical power to the consumer without any interruption in the service whatever.

Taking into consideration the transmitting of electric power from a power house one hundred or more miles away, through a wooded and rough mountainous country, where line troubles are of frequent occurrence, no small problem presents itself.

The line troubles are eliminated, to a certain extent, by the use of a double-pole line. In case of trouble, the current is switched from one to the other. It sometimes happens that there is trouble on both lines simultaneously, or that the generating units or other apparatus at the power house suddenly give trouble, requiring the shutting down of the entire plant.

It is evident that we must have, at the sub-station, a reserve to take care of all emergencies such as are likely to occur even with the most approved methods of transmitting electrical energy.

What is required in Mr. Bennett's case is to supply a reserve of sufficient capacity to take the load immediately after the main supply is shut off, and to run all machinery long enough to get things in shape for a complete shut-down, or until the main supply of current is turned on. The length of time, during which this reserve would have to supply current, would probably not be more than one or two hours.

To supply this current, a reversible motor-generator set could be utilized, consisting of a synchronous motor, running free on the line, directly connected to a direct-current generator, which generator would charge a storage battery capable of running the same generator as a motor for at least one or two hours. When the main supply of current is cut off, the synchronous motor becomes an alternating-current generator, being driven by the direct-current motor, thus supplying the power to the different motors, lights, etc., located in the vicinity of the sub-station.

This arrangement of a reserve unit could be made entirely automatic, by the use of proper circuit-breakers, etc., the load being thrown automatically on the reversible motor-generator immediately after the main supply is cut off.

The cost of current to run this motor-generator set would be negligible; in fact, the synchronous motor could be utilized as a

compensator for leading or lagging current by varying the excitation of its field. Arrangements could probably be made, with those who supply the power, to furnish gratis the amount of power required to run the motor-generator set; they in return receiving from you compensation in the form of leading or lagging currents, which would greatly reduce the loss in the transmission line.

The installation of such a reserve would be more or less expensive, but, taking into consideration the fact that the maintenance of a continuous supply of power is absolutely imperative, the reliability it would assure would undoubtedly justify its installation.

ENGINEERING AND THE LAW.

By Frank P. Medina, Member of the Technical Society of the Pacific Coast.

[Read before the Autumnal Meeting of the Society, December 2, 1904.*]

Every society is naturally divided into two parts—into two systems of institutions that differ most widely from each other. These two sets of institutions may be called the operative and the regulative. The former comprises all those social activities that express themselves in products or constructions—the agricultural, manufacturing, and we may include the commercial. The latter, besides other controlling agencies, includes the governmental-military organization, the legislative, executive and judicial branches of government, with all their ramifications.

This division of societies into two parts is coeval with their existence. The division begins vaguely, and continues indistinct for long periods. At first, the productive activities and the governmental activities are closely commingled—the governmental part may be said to absorb the other; but in the course of social life the division becomes more marked. Individuals are specialized into producers and makers of things on one hand, and into regulators of things on the other. Finally, there are established systems definitely marked out—the operative and the regulative—each having its own workers and its own machinery.

I wish to emphasize the reality of this social division. The fact that, in our country, the same individuals are sometimes engaged in activities appropriate to one of these divisions, and at other times in those appropriate to the other, disguises the fact of their existence as fundamentally different systems. Business men, engineers, capitalists, become Senators, Congressmen, Presidents. The State Senates and Assemblies, to say nothing of local Boards of Supervisors and Boards of Public Works, are made up of persons belonging to the operative division; and all these people, leaving the activities of the governmental class, return to their private pursuits in the productive or allied class. Nevertheless, the reality of the divisions is shown in their permanency, even in those societies which have no written constitutions, and more clearly in those that have. Besides, it is apparent that multitudes of individuals spend their lives exclusively in each division, as in the army and navy, in the judiciary and the bar, on the one hand, and

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in the numberless producing and manufacturing interests on the other. The divisions are real, and each system is becoming more and more distinguished from the other as time goes on. The coexistence of an operative and a regulative system is a universal social characteristic.

Both these systems are the products of the wants and fears of individuals. They are the expressions of human feelings—human desires and aversions, human loves and hates, human hopes and fears. Men gather into societies for the better satisfaction of their wants, for the better protection of their lives. In seeking to satisfy their desires, they have entered multitudinous forms of activity, and these multitudinous forms, altogether unsuspected by those who were creating them, became divided into the two general forms referred to.

The natural genesis of these two great social systems is a very striking thing. No social compact ever produced it. Feelings, individual human feelings, co-operating and conflicting, issued in acts which were simply intended to satisfy those feelings. The two systems are the resultants of these acts—the unforeseen, unintended and natural resultants. They abide because they are necessary. Both are necessary to the satisfaction of the feelings of human beings aggregated into societies.

But when I speak of feelings, I mean the whole range of man's emotional nature—not the desires to achieve bodily satisfaction alone, but to achieve satisfaction of all his sensations, emotions and sentiments. Certain of these feelings drive their possessors to productive activities; others to regulative activities. The growth of the one is dependent on that of the other. A sufficiently powerful regulating agency must always accompany the operative agency, and the regulating agency has to be supported by a sufficiently extended sustaining agency.

Enough has been said about the general aspects of the question for the purposes of this paper. Let us now examine each of the systems separately, and so bring into view their bearing on the subject—"Engineering and the Law."

Looking first at the operative system, which is meant to include all activities that express themselves in material structures for the satisfaction of human needs, we perceive, for the purposes of this paper, that the activities, exerted by its members, create certain relations among them. Their work is carried on by means of cooperation. "I will do this for you, if you will do that for me." Something is given for something received. This simple agreement is the basis of the innumerable contractual relations which

characterize modern societies. The rise of the *régime* of contract has gone on with the increase of industrial activity. Contrasting the feudal system with the system of to-day, we are struck by the radical change that this growth of contractual relations has created. It has substituted a spirit of contract for one of status. We live in an age of contract. The change has been accomplished by increased freedom of the individual and his increased importance. It has been a change beneficial to society and to the individual member of society.

In passing, we must note that other relations, besides those arising out of operative activities, have arisen, such as the relations of parent and child, of husband and wife, of guardian and ward, of master and servant. Now, all these relations have been affected by the change, referred to, from the *régime* of status to that of contract; and beneficially affected, as a comparison between the rights and duties attending these relations in the past with those of the present will show. All that it concerns us here to note, however, is the existence of relations of different kinds, certain of which are more or less permanent in their character, and create, in turn, certain relations between the individual and the society.

It is also to be noted that intercourse between societies arises and produces relations which create rights and duties between them, as they do between individuals.

Turning now to the regulative system, we note that it arises from the need of defining and maintaining the relations above referred to. One of the necessities of social life is the establishment of some degree of permanence of such relations. Beginning in a vague sort of way, their forms unacknowledged and the powers and liberties arising from them uncertain and barely felt, the relations gradually, as social habits became more confirmed, acquired a greater degree of stability. If one did something for another, he more frequently received the return to which he was entitled. The mere lapse of a short time became no longer a good cause for repudiating obligations. Parents also began to feel the permanency of their relations toward their children, and husbands toward their wives. Masters and servants recognized, more clearly, rights and duties toward each other, and all social relations began to take on a more stable form.

This permanence among social relations is an equilibrium of the mobile order. The various social institutions become closely interrelated, so that a disturbance in one disturbs all. It is only by some degree of permanence among individual relations that stable social institutions become possible. Such an increase in perma-

nence naturally accompanies the change from the impulsive primitive man to the deliberate man of civilization. A relation of obligation must continue to exist until that obligation is discharged. Corresponding to this relation there must exist an appropriate state of feeling. In other words, the sentiment of justice must be present in some degree. When this sentiment becomes strong, the permanency of the social relations becomes great. Growing intelligence begins to take the relations into consciousness, and to realize the importance of their stability, although it is only after ages of social intercourse that this conscious recognition of social relations takes place. For long periods such relations arise unconsciously as the resultants of the activities of mankind in the pursuit of their own private gratifications, and their increase in permanence is just as unconsciously produced.

We see, then, the operative system comes from the need of human sustentation; the regulative system from the need of social order. The activities of the former kind result in the production of food, clothing, habitations, as well as works of art; the activities of the latter result primarily in the establishment of permanent customs. The former activities create certain relations among the actors, which have certain obligations belonging to them; the latter insist on the strict performance of these obligations, and the forms that must be adopted in their fulfillment.

As time goes on, both these systems increase in mass, become more varied within themselves, and, while becoming more clearly defined from one another, are yet bound closer and closer together.

Originally confined to the production of food, clothing and habitations, the activities of the former system have been extended to the satisfaction of all kinds of needs. Within each group of activities there has been going on a change which is essentially the same in kind as the change in other groups. The change in the food-producing activities, for instance, is from a simple, inexact, inefficient way of doing things, to a complex, precise and efficient way. The advent of the plow and the flail, inefficient as these instruments are, marked a step in the process. Weapons of the chase increased in accuracy and efficiency. There is no need of tracing the changes in detail. A glance at the massive, exact, efficient food-producing machinery of to-day is sufficient.

The same change has taken place in the production of clothing. Here the liberal arts have called forth activities in the most varied ways. Spinning, weaving, dyeing—see the infinite variety into which the need for clothing has driven man's activity. Note, also, the improvements in machinery that have accompanied these

changes. Increase of mass, increase of variety, increase of definiteness—the same process throughout. A like variety is observable in the products themselves; from the comparatively uniform dresses of the past we see a change to clothing immensely varied in texture, form and color. Along with the manufacture of clothing, manufacture in general grew, arising in the same way and developing along exactly the same lines. The creation of habitations began in an uncertain sort of way by methods extremely inefficient, and all being similar in modes and products. It is a long way from the savage hut to the twenty-story steel building, but the route has been along the same road that characterizes progress in general—from a state of more or less undefined notions to one of scientific exactness; from a single mode of accomplishing the desired object to a multitude of modes; from a vague simplicity in the products, and an ill adaptation to the wants to be satisfied, to a definite complexity and an almost perfect adaptation.

We are gradually coming to the pertinence of these remarks to the subject of this paper—"Engineering and the Law." Meantime, let us note that the practice of barter arose, and that commerce grew out of it. Note also that the growth of commerce out of barter is also a change exactly like that which manufacture has undergone. Complexity, definiteness, heterogeneity, have replaced simplicity, vagueness, homogeneity, while the mass of activities engaged became greater. All this time there has been a closer binding together of all these interests, as is obvious in the cases of manufacture and commerce; and here, also, we must think of the growth of the higher emotions and sentiments, to whose gratification manufacture and commerce have contributed in so high a degree. I do not like to hear artists and literary people classed among nonproducers; the fine arts themselves are productive activities. They satisfy human needs of the highest order, and whatever satisfies human needs is, in a broad view of political theory, a productive activity.

But commerce and manufacture do something more to human wants than satisfy them—they produce greater wants. The race must now have more room to live in; things must be made in vaster quantities; distance must be traversed in faster time; night must be illuminated; ocean barriers must be overcome; uninhabitable areas must be made inhabitable; communication with distant places must become instantaneous.

Reverting now to the relations between men and between societies, which have grown up during this manufacturing and commercial development, we may note that they have become vastly

more numerous, better defined, and various. The rights and duties attending them have grown into customs. Social habits of loose, undefined forms have become permanent customs.

These customs become fixed and are more and more defined and controlled by the regulating system. The power of compelling them begins to belong to that system and is finally absorbed by it. The two systems act and react on each other. New ways of manufacture, further extensions of commerce, create new customs, and these have to be established and adjusted to prior customs. Efforts to satisfy newly awakened desires create further new customs, which must be established against the impediments which the existence of old customs always creates.

And thus we trace, in a rough way, the development of each of the two great systems into which human activities become divided; and we find these systems to be the products of such activities, while seeking satisfaction for human needs. We have reached the point in the regulative system where comparatively irregular habits have developed into manifold and fixed customs. We have next to observe that the final product of the development of the operative system is the great institution which forms one term of the subject of this paper—engineering, and that the final product of the regulating system is the great institution which forms the other term of our subject—the law; for as by further development under the demands of the expanded wants of mankind the ordinary activities of manufacture and commerce produce that higher form of activities named engineering, so the ordinary customs of mankind, by the increase of intelligence and justice, develop into the higher form named law.

Engineering has grown out of industrial activities; out of that higher class of industrial activities which aims not only at the sustentation of life, but at its augmentation. It is the outcome of the effort to satisfy the expanded desires which growing intelligence brings. It was not possible until the renaissance of science. With the awakening of the scientific spirit, men began looking closer into the properties of matter, force, time, space. Quantitative ideas were applied to the results of experiments. Instruments of precision were invented. Results were put to use to satisfy new desires. Machinery developed; land works multiplied; manufacture and commerce received tremendous impetus. Engineering as an institution had come to stay.

Engineering has developed in the same way that all other institutions have developed—along the course of universal evolution. Commencing its existence in a state of comparative vagueness and

uncertainty, with its theories ill defined and incoherent and its practice similarly characterizable, it has progressed, as it grew in mass, to a state of variety, its theories clearly defined and extremely coherent, and its practice justifying prediction by results.

The well-marked divisions of engineering into architecture, civil and mechanical, have developed into electrical, mining and others, with an ever-growing tendency toward further differentiation.

As customs become more fixed and general, they change into law. This change is well illustrated in Blackstone's "Commentaries of the Laws of England." The general customs of the realm, long before the time in which he wrote, had become the common law. Without enactment of any kind, the customs of the people of England had grown into a form so definite and had become so generally prevalent as to be properly called laws.

But these customary laws were fitted only for an age of comparative simplicity. The birth of manufacture and commerce saw changes in these laws corresponding with the new relations hence derived. The changes took place in three ways. Where it was found that a rigid application of the law would work injustice, legal fictions were often resorted to. Legal fictions assumed, for the purposes of justice, the existence of a state of facts altogether different from the real state of such facts. The device has largely passed out of the legal practice of the present time, the other two ways of promoting justice having superseded it. These other ways consist in the application of the principles of equity, and in directly changing the laws themselves by legislation. Equity is defined as the correction of that wherein the law, by reason of its universality, is deficient. The rise of equity jurisprudence obviated the necessity of resorting to legal fictions for the attainment of justice. The law here, it must be confessed, so far as our source of it is concerned, borrowed these principles from another part of the regulative system—the ecclesiastical, by whom it was introduced into England from the civil laws of Rome and administered by the Chancellors, who were, for a long time, members of the Church, and not lawyers.

The third way of adapting the rules of common law to the more intricate relations of modern society is by direct legislation. This is the most effective mode. Of course, its adaptation to the purposes intended depends on the intelligence and probity of legislatures. But, as to this, we must remember that laws are as easily repealed as made, and unjust laws are not allowed to remain on the statute book.

The laws of every one of the United States, excepting Louisiana, are derived from the common law of England. The principles of the common law are the basis of them all, but they have been very much amended by legislation. The laws of California, for instance, while they are based on the common law, have been so changed as to more nearly resemble the civil law. A San Francisco lawyer, of forty years' practice, once remarked to me that he had heard Blackstone cited only three or four times during his whole legal career.

Relations that have grown up between nations in modern times have created a large body of international law for their better definition and enforcement. And it may be said of both international and municipal law that the changes are in the direction of a juster order. This simply means that they are becoming better adapted to regulate, for justice is the adjustment of conduct in the best form to insure social stability. These changes are all evolutionary in their character, following the same course as the changes several times pointed out above.

And so we are thus brought to see that the fruition of the operative activities is engineering; the fruition of regulative activities is the law. They stand forth as the noblest products of the class of experiences to which each belongs. "As the thoughts of men are broadened with the process of the suns"—as the emotional nature of men deepens and widens—there come into being a scientific system of engineering on the one hand, and a just system of laws on the other.

The prime factor in the progress of civilization is the subjugation of force. On the one hand, the natural forces had to be brought under man's control. Man had to discover the art of pitting them against one another, and of converting one form into another. He had to use his knowledge in the construction of great stationary works, and immense machines. All this was the work of the operative system; co-operative labor produced it all. In order to accomplish it pure scientists had to discover the most abstruse qualities of these forces, and of time, space and matter. These discovered qualities were to be used in material structures for man's benefit. And along with this subjugation of natural forces there had to go a subjugation of forces of a very different kind. The erratic forces of human nature—human desires moving to unforeseeable actions—had also to be subjugated. The rights and duties arising along with the multiplied relations which came into being in the growing civilization had to be defined and maintained.

Irregularities of human conduct arising from uncontrollable

feelings would render a civilized state impossible. The control of these human forces is the province of the regulative system, and so we have the subjugation of force as the prime factor in social progress.

The part that engineering has played in this subjugation process is that of leader, master, commander of the operative system; it has shown mankind how to adjust the forces concerned in the building of cities; it has taught manufacture to adjust natural force to do work for man's benefit, and commerce how to adjust such forces to surmount barriers of time and space. Engineering has done this and much more, and so we are justified in claiming for engineering the paramount position in the system.

The law occupies a like position in the regulating system as the chief subjugator of the other kinds of forces. Before men begin to act on the abstract principles of ethics their conduct must be disciplined by the law. Ethics itself is only a further development of law. Conduct consists of acts adjusted to ends. In civilization many acts become inimical to social life that were appropriate enough to the preceding state. Many of the ends are also inimical. Yet the forces of human desires impel men to do these acts and to seek these ends, and will continue to do so until human nature has become completely adjusted to the social state and there needs no law but ethics. To control these forces has been the province of the law—to pit one against the other, as engineering has pitted force against force; and as in engineering the result has been stable structures, so in law the result has been stable social structures. The law has done this more than any other controlling agency, and so it occupies the paramount position in the regulative system that engineering does in the operative system.

Thus, engineering and the law stand forth as the great factors of civilization. The products of engineering have done more than any other products for the material good of mankind, and the law has been the principal means of maintaining man's enjoyment of these good results.

The making of civilization is not yet complete. The making of engineering and the making of the law are by no means finished. The needs of mankind are ever increasing. Society turns to the engineer to satisfy them in the future as she has done in the past. New legal relations are ever springing up, and society turns to the law with hope and confidence that she will in the future, as in the past, define and regulate them with always a nearer and nearer approach to perfect justice.

TRADE SCHOOLS.

By Edward Thomas Hewitt, Member of the Technical Society of the Pacific Coast.

[A paper read before the Autumnal Meeting of the Society, December 2, 1904.*]

What is the necessity for such schools, what are they accomplishing, what possibilities have they for future development, what is their present status? The subject is one so broad and deep, that it affects the whole social structure. The stability of a nation depends largely upon the welfare of its people, upon their fitness for the many pursuits of life, requiring constant and serious consideration. Recognizing this to be the case, the utmost attention is given to the education of the youth of our country. The public school system will always maintain its proper position. The trade school is coming prominently to the fore, and is an influential factor in the preparation of young men and women to be successful in their life-work.

There are two great problems that open out before everyone: First, how to get a living, and second, how to get the most meaning out of life. Often the first overshadows the second, until the latter has become, to many, a half-forgotten dream. It has been a source of great pleasure and benefit to me, in the past, to have been associated with men who had learned their trades under the old system in this and other countries, and I can testify to the fact that they were thorough workmen.

Conditions have changed a great deal since those men first started out on their life-work. Sometimes in the past it had been maintained that the shop was the best school in which to learn a trade, and that the sooner a boy entered the shop as an apprentice, after acquiring the rudiments of a common-school education, the better it was for him. That may be true, where a boy's only desire is to become and remain just an ordinary workman. There are, of course, some exceptions to this rule. The general prosperity of the present time permits the parent to give his children a better education than was formerly obtainable. The trade school of to-day aids materially in the accomplishing of this purpose. The graduates are demonstrating to employers their superiority, acquired through proper training for their chosen lines of work. After the boy has graduated from this school, obtained employment, become familiar

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with shop methods, his education proves its real value. The results have been very encouraging to all concerned.

The general tendency nowadays is toward obtaining an education before looking for regular employment. This means a more effective power for work. I have frequently seen young men make great sacrifices, in order that they might be enabled to continue at school. The future years will prove the wisdom of their present application to study. We find the sons of professional men, mechanics, farmers, miners, business men and of manufacturers, in short, men representing many classes of society, earnestly working side by side in trade schools, this class of school being just what they wanted. To many, ordinary school life had been somewhat distasteful. Boys of fourteen years of age pass through a period of physical transition, their bodies and minds are growing and developing rapidly; hence the great care that is necessary at this time, as their whole life is shaped by the course that is taken by them then. Of the children who enter the grammar schools a very small percentage reach the university.

As a basis for this discussion, allow me to submit some statistics on school attendance. The school census of this city and county, for the year 1901, stated that there were 105,512 children under 18 years of age. Of the 82,173 children between the ages of 5 and 17 years, 48,517 are reported as having attended school at some time during the year. The average daily attendance was 34,771. The number of children, between the ages of 5 and 17 years, attending private schools during the year was 10,586. The number of children of school age, who have not attended school at any time during the year, was 20,634. The report states that while the school age in our own State extends over eleven years, from the sixth to the seventeenth year of life, very few pupils attend school for that length of time. The average child has a little more than 6 years' schooling. San Francisco ranks well with other cities of this country in school attendance.

The efficiency of the secondary school has been greatly increased through the introduction of manual training and industrial work. Boys having a natural aptitude for mechanics are now desirous of entering these trade schools, as they give them a better opportunity for developing their talents and for finding out for themselves what particular line of work they are best suited to follow. In former years boys did not have this opportunity. A large majority of the graduates of grammar schools entered for employment at almost anything they could find to do, having no definite plan in view. If they chose a trade, they possibly attended

a night school. Many a boy has gone through life totally unfitted for any particular calling. Restrictions as to the number of apprentices still further placed him in a precarious position.

Young men must obtain some kind of employment, employers cannot conduct their many enterprises without the aid of skilled help.

While the author fully recognizes much good in the old apprenticeship system, it is evidently inadequate under present conditions. Business is conducted by employers for profit, and it costs something to teach the apprentice his trade, so the boy often loses a great deal of time doing rough work. If he shows an aptitude, he may possibly be given some small job on which to try his skill. If he spoils it, some time may elapse before he is given another opportunity. As a rule, in the average shop, he has to shift for himself.

Cheap help proves to be the most expensive in the long run.

It may not please some educators to have to consider the utilitarian phase of education. But then, every head of a household cannot afford to send his children into the higher schools, unless he sees future possibilities which warrant his doing so. Therefore, the schools must adapt themselves to his wants, and reserve the university courses for those who are better able to take them. The trade school here finds its place, proving its worth, which is now universally recognized.

The old order changeth, gradually giving place for the new. August Belmont, the man who financed the stupendous Subway undertaking in New York City, in commenting on the opening of the Subway, recently remarked philosophically to a friend: "That I am pleased that the Subway is at last completed, goes without saying. But, the longer I live, the more keenly I feel that, whatever is good enough for us to-day, is not good enough for us to-morrow. The Subway is only the beginning of great things in its line."

Now I will endeavor to sum up briefly the various avenues of employment that are open to the young man. Graduating from the grammar school, he may, if so inclined, enter some large iron works to learn a trade, and attend a night school to study arithmetic, mechanical drawing, physics, geometry, science, etc. If the boy is of the right sort, he will stick to his work and studies, thus qualifying for advancement. Very often it happens that he has nobody to direct his efforts for mental improvement. Employers have no special interest in his welfare, and there may be no suitable night school available to attend.

Some of the representative firms of this country, feeling the

need for more high-grade workmen than could be obtained in the old way, decided that it was imperative to give closer attention to the care and training of the young men in their employ. This has been productive of very good results. The young men, in turn, appreciate the efforts in their behalf, and are as proud of their shops as any university graduate is of his Alma Mater. The Baldwin Locomotive Works, Brown and Sharpe Manufacturing Company, the Westinghouse Electric and Manufacturing Company, are notable instances of firms which are solving the apprenticeship question. Each of the aforementioned firms has an experienced man who has complete supervision of the apprentices. He examines them in the first instance to see if they come properly prepared, and upon their preparation depends the group in which they may be placed, of which there are three. First-class apprentices comprise boys who have had a good common-school education and who are not over 17 years of age. Second-class apprentices are boys who have had an advanced grammar or high-school training and who are not over 18 years of age. There is also a special course of instruction for young men over 21 years of age who are graduates of colleges or technical schools.

The director of apprentices sees that each apprentice receives a full and sufficient training in his particular work, and also directs the studies, choosing the particular school which they are to attend. He stands as guardian for them in many respects while they are in the city, as many are from other parts of the country.

The director is really a school principal in these large works. His efforts promote system and efficiency, and these are what his employers want. In reality, this is an ideal type of trade school. It is the outgrowth of the urgent necessity for high-grade work. This particular apprenticeship system at present is limited to a few noted manufacturing companies. It is practically putting the school in the shop. This, no doubt, would please our old friend, Professor Sweet.

It is hardly possible for smaller companies to follow the example set by these firms. Trade schools must fill the gap. They are now giving to young people a thorough and systematic training in a very large number of industrial pursuits. In the future it will be the graduates of these schools, who, after a riper experience, will naturally assume the leading positions in the industrial world. I would like to add that the schools of San Francisco are amply able to give our youth the training they require.

If a young man intends to study law, medicine or theology, the regular high school, giving the classical course, is preferable.

If he has a business career in view, the commercial school will help him. To become a successful farmer, a course in a school of agriculture is to the purpose. If he desires to become a professional engineer, in some one of the many branches of the art, a college preparatory course in a mechanic arts school will give him the necessary preliminary training. The young man who wishes to learn a trade, and also to obtain a good education, would do well to spend four years in a school of industrial arts. It will be time well spent. These schools are enabled to offer good inducements, having an excellent equipment, efficient instructors and practically free tuition. The school day is of longer duration than in the common schools. Thus it is possible to accomplish a great amount of work during the term.

Educators, philanthropists, statesmen, men of affairs, have given their time and money to further the advancement of industrial education. Mistakes have been made in the past, as in all new and important undertakings, but they are gradually being remedied. Industrial education has passed the experimental stage. The splendid schools, now open to students in this and other countries, testify to the universal need of them. To speak of some of our local institutions, I might mention the Wilmerding School of Industrial Arts, founded by J. C. Wilmerding; the California School of Mechanical Arts, founded by James Lick; Coggswell Polytechnic College, founded by the late Dr. Coggswell; Polytechnic High School; Drawing Department of the Humboldt Evening School; the California Polytechnic School, a secondary school of agriculture. The foregoing are secondary schools.

For those who desire to study for a professional life, the University of California and Stanford University are amply prepared.

Passing through the many different departments of a large modern school devoted to the training of young men in the mechanic arts, the question arises in our mind, What would our youth do if such schools did not exist? Observe them carefully, see how engrossed they are with their work. They have learned the secret of being happy through occupation. Greater interest is taken in mathematics and science, for the students now see their application. The knowledge of free-hand drawing enables them to make quick, serviceable sketches. The study of mechanics, including the strength of materials, helps them in machine design. Boiler and engine tests are conducted under the most favorable conditions. In the school devoted to the building trades, everything is considered that is necessary in the construction of a complete building. Agricultural schools will enable the future farmer to manage his

farm to better advantage. The field of industrial chemistry is now offering abundant opportunities.*

Such an earnest desire is shown by the students, that the noon hour is utilized by many for work, as they do not want to lose a minute. Discipline is maintained not by severity or strictness, but by leaving the students on their honor to conduct themselves in a proper manner. The greatest punishment we can inflict is to compel a student to remain out of his class. Much interest is taken by them in athletics, music, debating, etc. The experiments in the laboratory, work in the shop, studies in the class room, track athletics, social pleasures, are taken up with enthusiasm. Under such influences, a splendid type of man is produced.

Having had the opportunity to observe closely the results of apprenticeship in the shops, and of training in the special schools, I feel confident in saying that the school method has, in most cases, the advantage. We have letters on hand from employers, parents and graduates which prove our statements. Of course, there are some boys whom no amount of schooling could improve, just as there are boys in the shops whom no amount of adverse circumstances could hold down. In its broader meaning, the school gives the greatest good to the largest number. Applications for entrance next July are already on file in many of these special schools.

The Wilmerding School of Industrial Arts for boys was founded by Mr. J. Chute Wilmerding, $400,000 being left to establish and maintain a school to teach boys trades, fitting them to make a living with their hands, with some study and plenty of work. The school is open to any earnest, industrious boy who wants to learn one of the building trades. Any boy who has completed the grammar-school course is eligible for admission. It is intended to give something more than the mere equivalent of a workshop apprenticeship. Its graduates must have a fair command of the English language. They must know enough of mathematics, drawing and science to insure intelligent and progressive workmanship. But, with all these things, the student must acquire a thorough mastery of his trade. He must become a skillful, rapid and thorough workman. The trades taught are carpentry, architectural drawing, plumbing, cabinet making, electrical working, bricklaying, blacksmithing, wood carving, clay modeling. Four years is the course. The new brick buildings of this school, also an enlargement of the Lick School buildings (including the many branches of

* The girls, in addition to their academic work, are taught domestic science. The value of all this is apparent.

detail work involved), are being built by the students, and are attracting much favorable attention.

The California School of Mechanical Arts was founded by James Lick, and was endowed at a cost of $540,000. Its object is to educate boys and girls in the practical walks of life. The school is free of charge for tuition, and is open to any boy or girl of this State who has completed the eighth grade of the grammar school. The following trades and technical courses are given:

Boys.	Girls.
Forgework.	*Industrial arts.*
Iron and brass molding.	Cookery.
Machine-shop practice.	Dressmaking.
Electrical construction.	Millinery.
Machine and ship drawing.	
Industrial chemistry.	
Polytechnic course.	

The boys and girls are eligible for a technical college preparatory course. Four years are required for each trade. A full academic course is given in conjunction with the trade selected. A short term is devoted by each student to each of the foregoing trades, and is called the manual training or preliminary course. This covers the first two years. They are then re-classified, and the student may take up further studies, to prepare himself for the technical college or university course. Again, any student, who may not care to specialize in any of the courses given, may pursue a general elective course, made up by selection from the various subjects offered in the different departments of the school. This is called the polytechnic course. To avoid dissipation of effort on the part of the student, and to prevent him from taking up work for which he is unfitted, his progress must be approved by the instructor in charge of each department concerned.

A large number of students choose the trades courses. During their term of apprenticeship, the major part of their time is devoted to a practical study of their trade in all its forms; as large a variety of work as possible is given. Such studies as are necessary for efficient work in their trade are required, viz: mechanical drawing, strength of materials, mechanics, boiler and engine tests, mathematics. The class of work done is of an educational and practical nature. The instructors in charge are men who have had practical experience. I might mention that several castings have been made recently, each weighing 1800 pounds. Electric motors, steam pumps, machine tools, hoists, steam engines, an electric traveling crane of

2500 pounds capacity, and many special tools, have been made by the students in a workmanlike manner.

The Coggswell Polytechnic School, under its new principal, intends so to shape its policy as to include a course of mineralogy and assaying. In time a practical mining course will be adopted. Graduates of the eighth grade of the grammar schools are admitted.

The California Polytechnic School is a State institution, situated in San Luis Obispo. The purpose of this school is to furnish, to young people of both sexes, mental and manual training in the arts and sciences, including agriculture, mechanics, engineering, business methods, domestic economy, and such other branches as will fit the student for the non-professional walks of life. Its location is extremely favorable for its success.

The Drawing Department of the Humboldt Evening School of this city is doing a good work. Here may be seen 460 students spending their evenings, from 7.15 to 9.15. The course requires three years or more.

There are two classes in naval architecture.
One class in electrical engineering.
Two classes in architecture.
Six classes in mechanical engineering.

The last item is divided into the following special branches:
Two classes in special and automatic machinery.
Two classes in marine engineering.
One class in gas-engine construction.
One class in mining and mill work.

In addition to these there remain:

One class in geometry and trigonometry.
One class in algebra and advanced arithmetic.
One class in theoretical mechanics and electricity.

Lectures are given every Friday evening in each class by the class instructor, from 8.35 to 9.15. Semi-annually six lectures are given by professional technical men on the various branches given in the school. The instructors are men daily engaged in the branches they teach. The school has been established seven years. Its rapid growth and large attendance of students testify to the necessity for such a school and to the good work done by those in charge. Allow me to add that the social feature of so many earnest young men, meeting together every evening, is of incalculable benefit. Their minds are improved, daily work is raised in quality, employers are benefited. Many life-long friendships have their beginnings where such conditions exist.

In the Polytechnic High School of our city, a very good course is given in mechanical drawing, woodwork, machine practice, wood carving, clay modeling, free-hand drawing. Many of the graduates are employed in our various shops.

Children in the public schools are now given elementary instruction in woodwork.

Throughout this country there are many schools that have been established in recent years, notably the New York Trade School, Pratt Institute, Worcester Polytechnic Institute, Drexel Institute of Philadelphia, Cooper Institute of New York, Armour Institute of Technology, Chicago. The reputable correspondence schools are assisting young men who would otherwise remain without any systematic training.

In the South, Booker T. Washington is trying to solve the negro question by education. He has established a school of trades at Tuskegee, Alabama, and, by encouraging thrift and industry, he expects to raise the standard of living for the colored man.

The Kamehameha Schools, in the Hawaiian Islands, were erected for the benefit of the native boys and girls. Instruction is given in the common English branches, manual training, sewing, tailoring, printing, practical agriculture, carpentry, forgework, machine work, painting and electrical work. This school was founded by Mrs. Chas. R. Bishop.

Every country needs skilled workers along many lines of industry. It is interesting to note that modern methods are invading the cities of the Orient. The Philippine School of Arts and Trades has been established in Manila, offering to the native young men an excellent opportunity to fit themselves for positions in industrial lines of work. The people of these islands have much latent mechanical skill, and the object of this school will be to develop this ability, guide it into modern channels, and foster a sentiment in favor of honest labor.

The Japanese recognized the benefits of industrial training long ago, and were quick to adopt it. In England and Scotland, many schools are doing excellent work. The idea is gaining in favor, in fact, it is becoming a necessity. Competition, in the markets of the world, with the United States and Continental Europe, is compelling new methods to be adopted.

In Germany, industrial chemistry has created new lines of manufactures and revolutionized old methods. Mr. Carnegie and Mr. Schwab, Sir Philip Magnus and many others have given much of their time, labor and means for the improvement of men, and methods of performing work.

At the laying of the cornerstone of the new building of the Hebrew Technical School for girls, now being erected in New York City, former President Grover Cleveland, in his address as presiding officer of the exercises, said: Public appropriations and private charity are mindful of men and women in poverty, sickness and distress; orphan boys and girls are compassionately cared for and sheltered, but it was an inspiration of genuine benevolence, which led to a different field of human endeavor, and to the establishment of an agency for good which goes farther than to furnish the objects of its care with food and raiment, and the things that perish with the using. Here, girls and boys, who would otherwise be shut out from opportunity for needed improvement, are to be taught remunerative occupations, and thus the thoughts and inclinations of these children will be so molded as to affect our citizenship and our country's weal for years to come."

Periods of prosperity and of depression will always recur, but the path of modern civilization will always have an upward trend.

We should feel proud to be citizens of this beautiful city by the Golden Gate, in this wonderfully productive State of California, where the sturdy pioneers paved the way for us. History proves that engineers have also had a prominent place in its development. The many gifts which nature has so bountifully bestowed afford opportunity for the employment of a very large number of people. One of the greatest forces in the civilization of the present generation is being manifested through the mechanic arts. The magnificent ships of war, steam and sailing vessels; the splendid machinery constructed for mining, milling, manufacturing and power plants; the handsome buildings that grace our city, testify to the great ability and skill of our engineers, architects and mechanics. The construction of the Panama Canal will require much machinery. Who can tell what position our Western cities will take when the canal is finished?

Classes of work are so diversified that specialization in the schools is necessary. To avoid dissipation of effort, and to obtain the best results, different schools are allotting to themselves certain spheres of influences.

The California School of Mechanical Arts intends to add to its curriculum, at some time in the future, such trades as belong to the field of mechanical and electrical engineering and marine architecture.

The Wilmerding School will confine itself to the building trades, the Coggswell College to the mining industry, and the California Polytechnic School to agriculture, etc.

The employer, the employe, the educator and the heads of households must consider this vital question of education. Professional men have always taken a personal interest. We would, therefore, especially invite our citizens and civic bodies to visit our many institutions and to see for themselves what is being done for the uplifting of the youth of our city, developing them in the fullest sense of the word, making them better men and women and teaching them to enjoy life as the Creator designed they should.

DISCUSSION.

PROF. W. F. DURAND, of Stanford University.—How the training of our future mechanics is to be divided between the schools and shops, I cannot tell, but I believe that there will be room for both. Each has its mission, as there are certain things the trade school can do better than the shop, and others which the shop can do better than the schools. The two institutions ought to be combined. The trade school is of special value.

After all, life is something more than living—it consists in living and enjoying the good things of this world, and if the student can gain a little broader view of the world, or cultivate good taste in literature, becoming more of a man and getting more out of life, he is at the same time gaining something which will enable him to make a better use of life. The secret of instruction is development, and keenness of attention to things outside of himself. Very few are sensitive to a high degree, but when one is found in the hands of a good teacher, then the highest type of man is developed.

The schools are for the purpose of turning out a mechanic, a workman, while in the shop the output is to be a piece of machinery, etc., to be sold at a profit. Schools cannot do everything. The question of labor cannot be handled successfully in the trade schools. Each has its mission to perform, and, if we can only find the right combination, they can work together for one purpose.

As to the need of cultivating skilled labor as a necessity for maintaining our position in the industrial world, it has been proved over and over again, in the shop world, that repetition work saves both time and labor, and both have thus been enormously economized. The products of industry can be manufactured with vastly reduced cost if we will only find the right process of production. Our present processes are imperfect and admit of improvement, and the question is only to find out how to make the improvements so as to produce the items in the quickest and cheapest way. The trade school is simply one step in this general development of

skilled labor. Whatever may be our future, as determined in the next 10 or 15 years, our progress will be, in a great degree, due to the good work which our trade schools are doing to-day.

Prof. C. B. Wing.—Education is the development of a person; it is his capacity to see things, and to use what he sees for benefiting himself and the world at large. The desire for education is, primarily, the purpose of providing a livelihood, and a wish to make this world a better place in which to get a livelihood. We must not only teach a person's mind to see things, to reason, to express what he sees and to draw a conclusion from his observations, but he must also be able to apply his intellect to some practical purpose in the bettering of his condition and that of the world around him. Thus, the boy who is raised upon the farm has less opportunity for training his mind than the boy in the city; yet, placing them side by side, the boy from the farm has had his manual skill developed, and, at the same time, his mental capacity, and he is not only able to hold his own with the boy who has had intellectual training in the city, but can also use his hands.

When we merely teach persons to do things with their hands for the mere sake of doing it, without giving the necessary intellectual training as a basis, it is hard to meet, in the trade schools, the condition of competition existing in the shop. Any task set in the school is merely play and not work, and there is where the shop has to take the place of the trade school. In the shop, the boy knows that if he does not do his work well he will lose his apprenticeship, and the workman knows he will lose his job. Thus, the object of manual training is not only to learn the work itself, but also for the intellectual development of the student, and to enable him to see how he is going to solve the problem of his daily life.

Mr. Marsden Manson.—I have gone through the Lick and Wilmerding Schools and have seen the type of work they do, and I was impressed with the interest the pupils take in their work.

In the South Carolina Agricultural College, cotton is manufactured. Every grade of cotton is raised. It is ginned, cleaned, carded, spun, woven and put in the shop for use, so that every manipulation of the cotton, from the seed to the cloth, is gone through there. There are 600 pupils. The college shows the wide range these technical schools are taking.

Mr. A. E. Roberts, Head of Drawing Department, Humboldt Evening School.—It is impossible to teach certain trades and certain lines of work in an ordinary trade school, and I believe that

the proper system of technical education is where the workshop and the school are intimately related. A combination of practical work, in the daytime, with evening training, including algebra, trigonometry, science, etc., is the ideal system of education.

The trade school has its mission. Its mission is to go along with work to a certain extent, but to undertake to teach to any man a trade is attempting too much. The schools can go to a certain extent only. The principal value of the trade school is to give a young man a good academic training, with an insight into the trade he selects. He will then become a first-class mechanic, for he will understand the whys and wherefores of the different problems he meets in the shops.

I find the trade schools do not pay proper attention to the important question of time. A young man, going into a shop from a trade school, does not properly understand the value of time. The school overlooks the importance of practical work, and thus the force of its instruction is lost.

I am a friend of the trade schools, but they have their limits, and I do not believe in carrying them too far.

In order to have practical men carry on the work of instruction the professors should do practical work on the outside, as in that way they are enabled to keep in touch with the work.

I indorse what you say about the workshop method of instruction, but I add that academic work should go on in the evenings.

Mr. Orion Brooks.—At one time I was for several years engaged in manufacturing, and I then employed apprentices, not very largely, but enough to understand the needs of an apprentice. At that time, some twenty years ago, there were no regular apprentice laws.

The employer lacks the incentive to teach an apprentice. In order to make an intelligent workman, a man must be something more than a machine, and, in order to be that, he must have some instruction, which it seems can hardly be obtained in the workshop.

It is almost if not quite impossible to impress on the pupil in the trade school the seriousness of his work.

Without the trade schools we would be very likely to fall behind in the various industries. The difficulty lies in making the trade schools comply with trade conditions. The trend seems to be toward incorporating commercial trade customs in the trade schools, which is very encouraging, as it comes nearer, year by year, to the conditions found in the shops, and when such conditions shall be reached, we can turn out from our schools thorough

workmen, who will be something more than machines, and who will find the doors of all shops open to them.

Mr. G. W. Dickie.—This is a very interesting paper and one that should command the attention of all technical men. I do not quite agree with Mr. Hewitt in regard to the trade schools taking the place of the apprentice system. The majority of tradesmen have been, and, I think, always will be, educated in the workshop. I noticed, however, four years ago, a tendency abroad to introduce a certain amount of technical work in the shops. I found this idea worked out and in operation in several of the large industrial institutions in England and in some places in Scotland. This I found especially the case in Berlin, where, in several large establishments, the apprentices had to spend two hours each day in the schoolroom attached to the works.

There is a large class of industries, which, from the nature of the operations, cannot be taught practically in any school. We could never expect to go to a trade school and get fitters, riveters, etc., for work in the shipyard—such work could never find a place in any school. Then, the commercial element is almost excluded from the trade training of the school; that is, the ability to do work in commercial competition with others forms no part of such teaching, and this is the most important part of trade education. One hard thing for a boy to learn is to be prompt at work when the whistle blows at seven o'clock, and to keep steadily doing effective work until the whistle blows at five o'clock in the evening, and thus acquire the ability to produce enough to enable his employer to keep him steadily employed, and give him the regular compensation for such work. The schools are not required to run a profitable business in order to keep open, and they thus fail to teach the most important thing that always confronts the tradesman; that is, that his production must be worth more in the market than the remuneration he expects to get for it.

I am quite interested in the subject, and I occasionally visit the trade schools, especially the evening schools for imparting technical knowledge to young men who are at work in the shops all day. They are doing a grand work, and they should receive support from all technical men. The day trade schools are also a great help, but we must not expect too much from them. I do not think that they can ever take the place of the regular system of apprenticeships in the shop. We have a large number of apprentices, about 600, but not many of them come to us from the trade schools.

The Author.—The great benefits of trade and technical schools to humanity are now universally recognized. These schools are now receiving the best attention from thoroughly competent and trained teachers, men of broad education and practical experience. There are many excellent night schools in all of the large cities, their work being supplementary in character. The good work that is being done by the particular schools aforementioned is so self-evident that argument against them seems futile. Shops offering instruction to their employes are so few as hardly to be noticeable in comparison with the large number of places which demand only routine work, and where the men drift along and do not develop in the proper way. How much better workmen they would be if they had a good education! Employers, educators of the proper experience and heads of families should come together and plan for a definite policy of instruction for the youth of our land. How often it happens that they are pulling in opposite directions.

In the meanwhile, the boy does not know what course to pursue. If he does obtain some kind of employment, the chances are he is unsuited for it. Give a young man or woman an opportunity to start life properly, with some definite goal in view, enabling him or her to enjoy life in the fullest and broadest sense of the word.

PHENOMENA OF MACHINE OPERATION.

By John Richards, Member of the Technical Society of the Pacific Coast.

[Read before the Autumnal Meeting of the Society, December 2, 1904.*]

Among the many agencies and means that contribute to the evolution and better performance of machines and determine their endurance and economy of construction, there is one, sometimes ignored and in all cases underrated—the phenomena of their operation; that part which is not computable or learned by rules.

This factor, element or condition, whatever it may be called, however strongly it may assert itself in results, is not regularly recognized in the engineering literature of our day; and the object of the present short essay is to urge its claims and importance upon those who are called upon to deal with machine problems—a long-suffering class of people, who need whatever aid can come from this or other source.

In static structures, that do not involve machine motion, or that branch of constructive work we commonly call civil engineering, there is a close relation with science; means and agents are becoming uniform and can be computed and results predicated with much certainty. Strains can be defined; the properties of material are ascertainable; and extraneous forces, such as stress of the elements, the stability, oxidation and decay of material, and even its deterioration by fatigue, are becoming known and computable.

In machine operation, however, the path is by no means so clear and perhaps never can be. Nevertheless, progress is being made, and some of the general phenomena of operation are becoming susceptible of computation and scientific treatment; but, as I believe, to a much less extent than is generally assumed and believed.

To present the subject in a practical way, I have chosen the only means that seem available when considering things not computable, that is by citation of observed facts, and I shall refer to some typical examples. First among these may be mentioned the evolution of apparatus to impel fluids, especially liquids, by centrifugal force.

This is seemingly one of the most simple of all means for creating pressure. A body of liquid, confined in a fixed circular chamber, or contained in a revoluble circular vessel, can be set in

* Manuscript received February 13, 1905.—Secretary, Ass'n of Eng. Socs.

revolution without other resistance than friction, and this can be reduced to a very low degree in vessels that revolve with the liquid they contain, creating almost unlimited centrifugal tension; but the removal of the liquid from the vessel or chamber, or its discharge, and the translation of its rotary energy into pressure involve various mechanical impediments, so that the art has been in evolution for half a century past.

This process engaged the attention of the celebrated French engineer, Emil Bourdon, who constructed machines that worked up to high water pressure—more than 1000 pounds per inch, it is claimed. Some work in the same direction has been done within a few years past, here in California, both with liquids and with elastic fluids, but with what particular results I am not able to say. I mention the method as one phase in the evolution of centrifugal apparatus that may in future have some importance.

During the latter half of the past century, which covers practically the development of the common forms of centrifugal pumps, in which the fluid is set in revolution in a fixed chamber or casing, we have had a maze of computations by eminent scientific men bearing upon the construction and operation of such machines; but, so far as I am aware, no clear or correct explanation of the phenomena of their operation or of the varied conditions of their use.

Such computations as we have were naturally based upon certain assumed premises derived from obvious hydraulic laws, and, to some extent, from experiments; but these latter have not been of a kind to disclose what we call the principle or mode of action, including the whole passage of liquid through the machines.

The main resistances that qualify effect were sought out and shortened into formulæ which are, in the main, correct. Arrangements and proportions were based upon such formulated data, and fifty years have since passed, with progress, it must be admitted, but, as I maintain, without providing a clear concept and treatment of what has been called the phenomena of operation. Strange to say, the impediment to such concept and treatment was confined almost wholly to the simple matter of returning the water, after its rotation, to a state of rest or service-flow, without a loss of the kinetic energy required to set the water in revolution.

That there was a good deal of mystery in this matter is sufficiently proved by the fact that a great share of the literature, relating to such pumps, has been devoted to the shape of the impelling vanes, a thing which modern practice shows to be of no importance and almost a negligible matter in constructive design. The function of such vanes is to set the water in revolution, and is but

little more, except as to a slight modification of frictional resistance. The body of confined water in revolution is the thing to be considered. The vanes, except as to the function named, are merely a portion of the mass in revolution, moving at a rate, relatively, which renders their shape and curves a matter of little importance.

It was or should have been obvious, from the beginning, that the only considerable loss of energy took place in the zone between the impellers and the collecting or discharge chambers; but it required, as before stated, about half a century to complete this discovery, or, rather, to devise apparatus that would adapt itself to this fact, and a manner of operating accommodated thereto.

The most successful attempt at preserving or utilizing the kinetic energy of the water's revolution was made a few years ago by Messrs. Sulzer Bros., of Switzerland, who introduced separating vanes in the dispersion zone of centrifugal pumps, to divide the water into distinct divergent streams and to preserve it from agitation until its energy was translated into pressure.

To accomplish this, the dispersion passages had to begin with an area that would collectively vent a particular volume of water at the velocity required to balance the head or resistance. Such construction, when the castings and internal surfaces were true and tolerably smooth, increased the efficiency of such pumps, for the higher pressures, about ten per cent. or more compared to those without a dispersion zone or when the water is discharged from the impeller directly into a collecting chamber; but, at the same time, it set up impediments and limitations of a very formidable kind.

The castings are difficult to make; the acute points of the dispersion vanes wear away; but, most of all, the pumps have to be driven at an invariable speed and to deliver a specific volume of water in order to gain this higher efficiency. There is also a very considerable increase in dimensions and in cost of construction, and it remains to be seen whether a satisfactory efficiency cannot be attained without encountering these impediments.

We are in no position to know the value of divided water passages in the dispersion zones of such pumps, until the cause of losses there is understood. A mass of water, moving at high velocity, is easily disturbed and broken up into devious currents and courses, especially when the water is moving in a circular path, and it is easy to conceive that rough cast surfaces and imperfect shape of the discharge-way produced the principal loss in an open discharge zone. Computation furnishes no clue to this matter.

The future will, no doubt, determine this, not suddenly, or as a discovery perhaps, but by a careful study of the construction and

adaptation of such pumps to the theoretical and also the practical conditions of design.

To make a theoretical centrifugal pump from computed data is quite a simple matter. A diagram, to cover or include the water passages through a pump, with a cross section as the volume and inversely as the velocity, the length of the diagram representing the acceleration and retardation of flow, will disclose a design theoretically correct, and would only require that such a diagram be surrounded by a confining chamber of sufficient strength.

In practice, however, such a scheme would fail. Every pump would become a special machine for a specific volume and head; contraction of the water passages would prevent the passage of solids, except those of small size; the disturbance by the roughness of interior surfaces and divergence of course would interrupt and modify the velocity of flow; the machines could not be cheaply produced by the implements of organized manufacture, they would fail to meet the diversities of use, and the cost would far exceed the commercial standards that now prevail.

The conditions of practical use demand that pumps be made, within certain limits, for both high and low pressures, or with a considerable range of adaptation to different pressures; they have to be employed for various liquids, pure and impure, viscous and corrosive, and to pass solids of various kinds, including sand and gravel. They must endure abrasive scour in their water passages and exposure of their journal bearings, and they must be provided against unequal pressure or lateral thrust on the impellers. Interior surfaces, where the velocity is great, should be in true contour and finished smooth, with other features which could be named and which lie wholly outside of what we may call a computed or theoretical construction.

These are the circumstances such as cause long periods of evolution, require extensive observance of the phenomena and conditions of operation, and have to be learned tentatively, by inference, observation and experiment.

I have reverted at some length to centrifugal pumping, but the like circumstances apply to nearly all fluid machines which, as a class, have received the highest possible scientific treatment.

For another example, turbine water wheels were made the subject of research by eminent French engineers, who, previous to the middle of the past century, commissioned and aided by their government, laid down laws and scientific rules to govern the construction of these important machines. It was, no doubt, the most thorough and successful attempt of the kind ever made, and

produced the three types of turbine water wheels known as the Fourneyron or outward flow, the Jonval or parallel flow, and the partial turbines or impulse wheels of Girard.

About 1850, the subject was taken up in this country by two American engineers, Boyden and Francis, who constructed, at Lowell, Mass., what have remained, to the present time, the finest examples of Fourneyron turbines on this continent. Mr. Emil Geyelin, a French engineer, came a little later to Philadelphia and introduced the Jonval type of turbines. The Girard type or partial turbines have not been successfully exploited in this country, if we except the wheels lately erected at Niagara Falls.

Here was a complete mathematical development of water turbines, carried out to a skilled construction and to operate at the greatest efficiency. The subject of the water turbine seemed ended, and the writer, who was then engaged in that bygone occupation called "millwrighting," assumed and claimed that this art, at least, had culminated. And so it had, in so far as efficiency was concerned; but there was another phase to be dealt with in the operating conditions.

The French turbines were refined machines, exact, expensive and adapted for pure water. Our streams are mostly in flat lands, fluctuating and turbid. Gravel, driftwood and other kinds of débris would not pass through the fine issues of the new turbines, and American mechanics began, in an experimental way, "whittling" out new models. In the French wheels, the running, finished and expensive elements were outside and occupied the extreme diameter, while the rough and inexpensive fixed elements were placed internally and were of relatively small diameter. This resulted in expensive construction and a slow rate of revolution, requiring strong and expensive gearing for transmission.

So accustomed were engineers to associate centrifugal effect with turbines, that radial or outward flow seemed an essential condition, when, in fact, it had little or nothing to do with the case. This was found out by experiment and should have been evident from the beginning.

The American mechanics, after many years of "whittling" out models, succeeded in turning the wheels "inside out," or inverted them, so to speak, making the internal or smaller elements the running part, so that the water flowed inward toward the center, then changed its course 90° downward in helical passages for escape. This was done entirely without scientific aid, in some cases even controverting scientific rules, and the result is the centripetal or inward flow turbine, the standard water wheel of this country, of

which a single firm has made more than 10 000, and the wheels have even found their way back to France. Their efficiency is fully equal to, or even greater than, that of the older types, and the cost of the wheels is about one-half as great. This evolution has required about sixty years, and present practice rests mainly upon observed phenomena and upon the operating conditions rather than upon computed data. There was not even a draughtsman in the works where were made the wheels that gained the highest award at the careful trials conducted at the Centennial Exposition, in 1876.

This whittling method, as it has been called, was certainly slow and unnecessary, but was followed by shrewd mechanics in a roundabout way at great and unnecessary expense in money and time. At least, this is the way the matter seems to us now, but we are undoubtedly proceeding in like manner in the case of many other less intricate machines, as posterity may point out.

In respect to the Girard type or impulse wheels, Weisbach and others had contemporaneously, or earlier, investigated the laws that govern the effect of impinging fluids, and such laws were carefully observed in the development of partial turbines in Europe, where such wheels are now the standard type for the open or impulse class; but on this coast, mainly by reason of very high heads or pressures and the accurate work required in wheels of this kind, there commenced, about twenty-five years ago, a modification suggested by the peculiar operating conditions, producing a new class, known as the "tangential" type.

The development of this was, to a great extent, another case of "whittling" out models, and the old experience had to be gone over again. Notwithstanding that a good deal of scientific data, relating to such water wheels, was furnished at the beginning by Professor F. G. Hesse, of the University of California, the phenomena of operation continued to be observed, and from various clues, modifications were made, down to 1900, when it was discovered that the double buckets could be passed into and out of the stream by once dividing it. Other final features in the design of such wheels were noted also. They have since taken on the dress and finish of proper design and workmanship.

In the case of elastic fluids, impulse motors or steam turbines have been more than a century in evolution, notwithstanding that more than 400 separate patents have been granted in Great Britain alone for inventions pertaining to these machines, some of them a century ago and many of them fifty years ago. Mr. Parsons, an eminent English engineer, who has been prominent in this work during later years, is, no doubt, one of the greatest living adepts in

the science of thermodynamics, and, as is claimed, he has forecast with much accuracy the development of his turbine schemes as they progressed from 48 down to 11 pounds of steam for each horse-power hour, but it is also claimed that he has expended half a million dollars in experiments. He has probably expended more than this.

If inquiry were made, Mr. Parsons would probably admit that not one-fourth of his data came from computed sources, and that the observed phenomena of operation and adaptation have comprised the other three-fourths.

I might mention Lenoir's gas engine, the first of the internal combustion class. I examined an old engine in 1870, the first successful one, and I strongly suspect that, aside from the operating phenomena, this machine has furnished suggestions for nearly all improvements since, except perhaps the graduated combustion in the Drayton and Diesel types, yet in evolution, owing to impediments that arise in construction.

A wider and more important example of evolution in operating phenomena is furnished by piston steam engines. I do not mean the thermodynamic development of these, which is the greater part, furnished mainly by scientific deduction and experiment, but to the mechanical evolution of their operating parts, which had to keep pace with the thermal problems.

The "elimination of the speed factor," as our worthy President calls it, not only in the rotative, but also in the reciprocating parts of such engines, is a wonderful example of experimental development.

Down to twenty-five years ago, it was a common object, in steam-engine design, to reduce surface and velocity in bearings, partly to avoid friction, and partly because reduction of weight and space were also incentives, but the operating phenomena of machine bearings was a mystery in so far as any scientific rules were available.

Forty years after the publication of General Morin's experiments, which established a generally accepted law of friction, we find that alignment and pressure were considered subordinate when compared with surface in bearings.

Alignment, or the fit of bearing surfaces, especially in the case of cranks, is yet a mystery, if considered in a practical way. The most careful computations, respecting the flexure of shafts, frames, crank disks and pins, fail to disclose the operating phenomena. One has only to observe the center of an overhung crank or disk, even of the strongest proportions, to see that it describes a visible

ellipse when under heavy strain and for reasons not explainable by computation. French makers of steam engines so dread this phenomena that, I believe, none of them employ overhung cranks.

Similarly obscure operating conditions exist in various other parts of steam engines, and proportions are, beyond question, based more upon observed operating phenomena than upon computed dimensions.

Bearings that operate under steam, slide valves for example, were scraped to a perfect fit; cylinders were bored out with a smooth, glistening surface under a belief that such fitting was theoretically correct, but, by accident mainly, it was found that the bearing surfaces performed much better when they were not smooth and in perfect contact. A film of interposed water or oil produced the uniform fit.

In crushing hard material, such as quartz, with metallic surfaces, it was naturally inferred that the metal opposed to the stone should be as hard as possible, but, for reasons not easy to explain, soft metal endures longest. Cornish rollers are now covered with rings or tires of soft, fibrous iron. The sand blast discloses a like phenomena. It is easier to bore a hole through a file with the sand jet than through a thin sheet of copper. An emery wheel will rapidly cut away tempered steel, but not soft iron. It is a problem of friability, no doubt, but is not fully explained.

The whole field of mechanics is full of unexplained phenomena and mysteries, such as the temper of steel, the fatigue of metals, their crystallization under rhythmic concussion, the inherent strains in molded steel, the surge and reaction of moving liquids under high pressure.

The purpose of this short paper is to call attention to the fact that the conditions of actual practice are often best met not by machines figured out and determined on a draughting board from scientific data and thus produced with exactness and success, but rather by such as have come to us through the long line of evolution and have been developed mainly by other means than computation.

Much that is written is apt to lead to the conclusion that scientific calculation alone suffices, in machine design, without the exercise of logical reasoning and practical observation of the operating penomena and the conditions of use. Academic institutions should, at least, temper their theoretical instructions with the required warning that the phenomena of the operation of machines must be a principal factor in their successful evolution.

DISCUSSION.

Mr. Thomas Morrin.—For efficiency, electrical apparatus, in very large units, requires large bearing surfaces, reducing the journal friction to a minimum. The first arc-light dynamos used in this city had extremely small diameter journals which produced a high journal pressure and excessive heating, which was, to a great extent, the cause of much unsatisfactory operation at that time. Now we never hear of it.

Another important feature along this line is the necessity, in alternating generators of high frequency, of a perfect revolution; that is, there should be no difference in the rotative velocity in any segment of the circle described by the revolving member of a dynamo in any part of a complete revolution. This is necessary where two or more dynamos are run in parallel on separate shafts driven by as many different engines, or water wheels.

All this apparatus must be provided with sufficient journal surface to allow of rotation on a fixed center for very long periods without any material deviation in any direction. This refinement has been developed by the requirements of the electrical apparatus of recent years.

Prof. W. F. Durand, of Stanford University.—The only point which has occurred to me is the difference which may result in the design of a certain line of machines, having in view economy, efficiency and mechanical ideal.

The solution may be so complex that it is of no use whatever from a commercial point of view. What I particularly thought of was the Page typesetting and distributing machine. It is said that something over a million dollars was expended, and as yet there are in existence only two or three machines. It is a mechanical marvel, capable of achieving the most astonishing results, setting up type by using a keyboard like a typewriter. This machine is a mechanical typesetter, taking the place of a human being, detecting broken type, etc. However, just about the time when it was approaching mechanical perfection, the linotype machine came upon the market and realized the same purpose by a very much less expenditure in money, by the development of the block of type set in line.

We also have the monotype machine. The solution realized by the linotype or the monotype is far ahead of the early type, as it is a commercial success.

THE MAN AND THE SHIP.

By George W. Dickie, President of the Technical Society of the Pacific Coast.

[Read before the Society, March 3, 1905.*]

I have decided to give this lecture under the general title of "The Man and the Ship;" first, because my friends usually ask me to do so, and, second, because I think the Pacific Coast needs good men and the Pacific Ocean good ships.

The grandest development in men and ships will, I think, mark the beginning of the twentieth century for its epoch, and the Pacific for its stage.

In this lecture, however, I am not to deal with any pictures of future developments, either in men or in ships, but rather to indulge in some reflections that have often occupied my mind while striving to accomplish two very important tasks—that of building good ships that will stand the "Battle and the Breeze" and building for myself a character that will carry me through the storm and stress of life's struggle.

We will inquire how these two things can go together. It needs a shipbuilder to understand how one-half of this subject can match the other, so I will have to ask my audience to trust me for the shipbuilder's half. As to the other half—that is, the man—you can take him for just what you think he is worth, only he goes with the ship.

By a man I desire to be understood as meaning a whole man, complete in every particular. Not a male man or a female man, but the combination of both, is my understanding of a man; and my ship is to be a first-class ship of the line, which ordinarily is referred to in the feminine gender, as she or her, and yet she is a man-of-war.

The difference between man and woman, as we find them in society, and what might correspond to them in ships, has, by a process of evolution going on in our time, become rather faint, and, in some advanced cases, scarcely distinguishable.

Not so very long ago, in naval ship society, the frigate was a consort to the man-of-war, and these two were "useless each without the other." The power of the frigate lay in manœuvring and in speed; she could always outsail the man-of-war, just as the woman can outsail and manœuvre all around a man. She, the frigate, was

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built on finer lines than the man-of-war, full and buoyant in the breasts, with a fine midship section, and gracefully rounded buttocks. These were desirable qualities in the frigate; and what a power she had to carry canvas! A frigate of the first class, under full sail, was a sight that never failed to stir the heart of an old man-of-war's man; and has it not always been the ambition of every man worth the name to have his consort carry all the canvas he could afford to deck her in?

But times have changed with frigates and with women. The old-time frigate has become a cruiser. Her rounded breast lines have taken the form of a wedge, with a torpedo tube in the edge of it; the fine midship section has been swelled out to hold boilers and coal bunkers; propeller wheels have taken the place of the great swelling sails, and the gracefully rounded buttocks have given place to the sharp stern line, so that there may be no eddies to affect the action of the wheels.

Like the old frigate, the modern woman has also become a cruiser, and she no longer plays a second part to her consort of the line. Her ability to carry canvas, owing to her new design, has been very much reduced, and those fitted with propeller wheels have had to dispense with all superfluous canvas, clew up the lower courses, and, where the channels are clear and there are no obstructions to navigation, they may be seen on fine days making good time with their wheels under bare poles.

With this much by way of introduction, it is my purpose in this lecture to compare the chief characteristics of a first-class man and a first-class man-of-war, and in this comparison I shall divide the subject into two sections, each having a group of characteristics which can be compared with each other.

The first group will be of qualities inherent in the design of the battleship—qualities which cannot be altered, but which may be modified by acquired qualities in her equipment corresponding to a group of inherent qualities in the man; those characteristics which were born with him, and which he retains through life, subject to modification by education and experience, but never to be entirely eliminated.

The second group will be the fighting and endurance qualities given to the battleship, represented by her propelling power; how long the source of this power will last; her means of offense and of defense, and the personnel of her complement.

In the man, this group of qualities is represented by education, power of will, industry, regard for truth and right, and faithfulness to duty.

The naval architect, in beginning his design for a first-class battleship, or for any other form of ship, must, like the architect of a building, decide first on the foundation. As the size and weight of the building determine the character and extent of the foundation required, so the size and weight of the battleship determine not the *character* of the foundation, for that is always the same, but the *amount* of the foundation.

On a foundation of piles and concrete on the lake front of the Columbian Exhibition, at Chicago, there was a full-sized model of a battleship built of brick and mortar; but such a deception was possible only on a lake where the water is always on the same level. The foundation was not a ship foundation at all.

The naval architect calls his foundation "displacement," and his unit of measurement for his foundation is 35 cubic feet, because that volume of sea water weighs one long ton.

In order that what I have to say in regard to my battleship may have a definite meaning, I shall take the qualities of the battleship "Oregon" as standard in this lecture.

The very first question the designer had to answer was, "How deep shall my foundation be?" The depths of certain docks and harbors must be considered in reaching a decision, and, knowing where the vessel had to go, this was fixed at 24 feet. This depth of foundation must therefore carry the structure he is to build.

Having this important point settled, he must now get information from other experts; so he calls on the engineer for the weight of all the machinery the foundation must carry; on the ordnance expert for the weight of all the armor, guns and ammunition the foundation must carry for him; on the equipment expert for the weight of all the outfit the foundation must carry for him; and then he figures out very carefully the weight of the structure itself, after which the experts must meet and decide how much weight of coal and stores and people must also be carried by the foundation. After which the whole is summed up, and the result is that the foundation must carry 10,400 tons.

He must now consider how wide his foundation will be. The position of the weights that he has to carry, above the base line of the foundation, help him to determine this dimension. Here, also, he consults all the gathered experience of his profession with the type of ship nearest to the proposed design, the result being that he decides on a width of 69 feet.

Now, if he had to build simply a rectangular structure, the weight of which was 10,400 tons, he would find that, at 35 cubic feet to the ton, the contents of the foundation would be 364,000

cubic feet; and, the depth having been settled at 24 feet, and the width at 69 feet, the length would therefore be 220 feet. This would be the smallest dimension of foundation that would carry the load, and it is called the box displacement; that is, a box 24 feet deep, 69 feet wide and 220 feet long if filled completely full would contain 10,400 tons of sea water.

Here a great many considerations present themselves to the designer. He knows that an increase in the length would give him fine lines and speed, with moderate power, but would detract from other qualities that a battleship should possess; and, speed not being everything in a battleship, he again has recourse to experience, and this tells him that the ratio between the length of his battleship and that of a box must be somewhere between 1 to 0.6 and 1 to 0.65. So he decides on 0.631, and this makes the length of our battleship 348 feet. This ratio between that part of the ship which is in the water and a box is called in America the box coefficient, and in England the coefficient of fineness.

On this foundation of displacement rests our battleship, and it is absolutely sure, if the weights are correct; but, if the weight exceeds by any amount the designer's figures, the foundation gives way correspondingly. The designer, therefore, must be sure of his weights, of his dimensions and of his coefficient of fineness, or his foundation will fail him. His ship will displace not an inch more than is provided for by the form and dimensions he has given her. If he makes an error either in weight, in form or in dimensions, some other desired quality must be sacrificed.

A man, like a battleship, is supported by his own displacement; and, if he is to hold his own in the battle of life, with freeboard enough for winter weather, he must have a high box coefficient. His only foundation on the sea of life is his power of displacement. A man, when launched into the world, finds no empty place made ready to receive him. No one scoops out a hole in the water to receive the ship; when launched she must displace her weight of the element into which she plunges. So a man displaces his weight of whatever element is opposed to him.

This law is as true of him as of a battleship, with only this difference: that the ship displaces but one thing, and by that she is supported; but man's power of displacement has no limit in kind, and in degree it is limited only by the bulk of the man.

What we, as individuals, are displacing is the coefficient of our power for good or evil on this earth. What we, as a community or nation, are displacing will be the coefficient of the power for good or evil of that nation on the human race.

In our designs for manhood, let our box coefficient, be it great or small, stand for the displacement of wrong by right; or of error by truth; of ignorance by knowledge; of idleness by work; of dead things by living things; of weakness by strength; of sorrow by joy, and of all evil things by things that are good. We must not forget that our power to do good in this world is simply our power to displace evil by the coefficient of our own goodness.

The displacement of the man, like that of the ship, is his foundation; that is, his character.

Having determined the amount and dimensions of the foundation that is to support the man-of-war, the naval architect must now deal with another quality—that of stability. Here a somewhat more complicated set of problems confronts the designer.

In a building, the more stability the architect can secure the better; but in a man-of-war, too much stability would be quite as undesirable as too little. It is therefore the business of the naval architect so to work out his design that the proper amount of stability will be attained.

Stability and steadiness do not always go together in a ship; in fact, they are sometimes quite opposite qualities. To secure steadiness, stability must be present; yet a ship may have a high stability, and, notwithstanding (in fact, *because* of extra stability), may be a very unsteady ship.

The stability of our man-of-war depends upon the positions, relative to each other, of two points; of these, one is the center of motion, the other the center of mass. The architect calls one the metacenter, and the other the center of gravity, and he expresses the stability of his design for a ship by the sign of an M above a G, and the distance between these points he expresses in feet and inches.

The metacenter is the point around which the ship moves in rolling. If only the seasick unfortunate could find that point he might there find relief. The naval architect finds it by taking the center of buoyancy of each of the sections he has made of his ship, and therefrom finding a mean center of buoyancy. The metacenter will always lie in a longitudinal vertical plane, bisecting the ship, and vertically over the center of buoyancy, and its position is found by dividing the moment of inertia of the load water plane, relative to the middle of the vessel, by the volume of displacment; that is, by the amount of foundation.

I do not expect you to understand this; it is not at all necessary that you should. So long as the naval architect understands it, you will be perfectly safe in taking his word for it.

The captain, who is to command this man-of-war, does not know, perhaps, how to find this important point in his ship; but the way in which she behaves herself at sea will soon enable him to determine whether it is in the right place or not.

Then the center of gravity must be carefully determined by the designer; and to do this he draws a line under the keel, and this he calls the base line; and, having found the position of the metacenter, he notes it as so many feet above the base line. Now he begins a series of computations in regard to the weight of every part of the ship; nothing must be left out. He also finds the center of gravity of every piece, and its height above the base line. He expresses the weight of every piece in tons, and its height above the base line in feet. He multiplies these two factors by each other, and expresses the result in foot-tons; and this is termed the moment of leverage of that particular piece.

Having thus determined the weight and leverage of every part, the total amount or foot-tons, divided by the displacement or foundation weight, will give the height of the center of gravity above the base line.

I do not expect you to understand this either, and it is not necessary, but the naval architect must understand it very thoroughly, or the result may be very serious, indeed.

The stability, then, of a man-of-war, or of any other ship, depends upon how much the M is above the G in her design. If they were both in one place there would be no initial stability, and the ship would remain in any position that she might accidentally get into; and if G were above M she would turn bottom side up.

This is initial stability, and it is an inherent quality in the design of the ship. It may be modified, after the ship is built, by taking in weights below, if G is too high, or by putting weights above, if G is too low; but the necessity for such corrections always reflects on the skill of the designer.

Now, initial stability is an inherent quality in the man, and without it he is a helpless hulk on the sea of life. His metacenter, like that of the ship, is the point around which he swings, the center of his affections. His center of gravity, the weight of those things that he carries about with him, must be kept well below the center of his affections, else there will be nothing stable about him. If his box coefficient be high, and his dimensions large, he may carry great weights of this world's goods. So long as their moment of leverage is not too great, and their combined center of influence is kept well below the metacenter, their effect may be beneficial, making him more comfortable at sea. So long as our earthly pos-

sessions, real estate, cash accounts, and other heavy things are carried in the lower 'tween decks, with a good metacentric height, our stability will be improved, and not impaired, by the load we carry. So long as we keep M well above G in all the vital matters of our life, we may safely put to sea with everything on board.

Through ignorance of the laws that govern the stability of a ship, those in charge of her often stow weights on board in such a position as to endanger her stability, going to sea only to meet disaster.

So a man often takes into his life things that he cannot carry. Let us be careful that those things do not lower our metacenter. Far better throw such weights overboard than struggle at sea without stability. So let us set our affections, that is our M, well above G.

A man-of-war or any other ship may have a large amount of initial stability, and yet be very unsteady at sea. If the ship is intended for river or harbor navigation, and is never to encounter rough water, then the more stability the better; but when amid waves, if the metacenter be too far above the center of gravity, the tendency to assume an upright position may be too great, and violent rolling may be the result.

In designing a man-of-war, great value is placed upon steadiness of platform; for, if that cannot be secured, she might have to fight under sea condition which would give her opponent, if a steadier ship, a fatal advantage.

So the naval architect tries the design he has made, in order to see whether her righting moment is sufficient and not too great. When he inclines or heels his design, relative to the normal water plane, he finds that the sections show that on the one side a wedge-shaped piece goes down into the water, while another wedge-shaped piece comes out of the water on the other side. These two wedges are called the wedge of immersion and the wedge of emersion. Now, if these two wedges were equal, the ship, when thrown out of the upright position by waves, would not come back again. But, if the wedge that goes in is greater than the wedge that comes out, the difference is called the righting moment, or power of shoulder, and if this is very great, the ship, when thrown out of the upright position by waves, would come back too quickly, and would have an unsteady and violent rolling motion in a sea way.

So the skillful architect will so modify his sections above the normal water line that the wedge going in will not be too much in excess of that coming out, and he will thus secure easy motion in rough water.

This question of steadiness receives careful attention in the designs for a war ship, because the weights to be carried are all known, and their positions are fixed in the design. The water line also is known, and it changes only with the consumption of fuel. But in a merchant ship, the designer has not so full control over the quality of steadiness, as a great range must be provided for in the position of the water line, and consequently much of the sea steadiness of such a ship will depend upon a skillful distribution of the cargo.

A man, like a ship, may have inherently great stability of character; his metacenter may be far above his center of gravity. In all ordinary conditions of life, he maintains an upright position, and, if smooth water prevail all through his life experience, his character will be admired, and others will point to him as a fine example of uprightness and stability. But let him get out into the open sea, amid the storms of life, where waves are high and great forces oppose themselves to him and his ways. It is then that his stability often degenerates into mere stubbornness; his righting moment is too great. Instead of rolling gently to the irresistible waves that beset him, and swinging gracefully back again to the upright position, when the wave has spent its force, he gathers all the power of his stability to fight against the natural forces around him, shipping huge seas in his desperate efforts to maintain his upright position; and, should the storm continue, he is apt to go down, a martyr to his own faith in inherent stability, to his sense of right.

As the naval architect tumbles the high wall sides of his ship home—that is, inside the perpendicular—to reduce the righting moment, and thus make her steady amid waves, so the man out at sea, when the storms gather about him, will find safety and comfort in tumbling home; there his rolling will be easier, and there he will have a steadier platform from which to fight his enemies.

Along with steadiness in rough water, the naval architect must so design his ship as to secure great *range* of stability; that is, he must maintain a righting moment sufficient to bring his ship back again, should she by some unusual force or combination of forces be forced far out of the upright position (and he generally constructs a curve or diagram that shows how far his ship can roll), and yet retain the power to recover her normal position.

In a man, I think that range of stability is a better and more desirable quality than initial stability without the power to recover a lost position when once driven from it. The man who, when beaten down and almost overwhelmed by opposing forces, still has

this righting power intact—that principle within him that tends for righteousness—this man comes triumphantly through the struggle of life, while another, with greater initial stability, but with little range of righting power, might be utterly undone.

Having thus settled the matters pertaining to the hydraulic and statical questions that affect both a man and a man-of-war, the naval architect must then determine on the best possible use he can make of the weights allowed him for the hull proper. His skill in doing so determines the structural strength of the ship.

In a man-of-war or line-of-battle ship, a very large proportion of the displacement, which, as we have seen, is the foundation or support, is given up to carry heavy armor for defense, and a powerful battery for offense; so that, of the total displacement, just about one-third is available for the hull structure itself. Great skill is therefore necessary in making a proper disposal of the material forming the hull. The usual method of framing, adopted on a merchant ship, where simplicity and cheapness of construction are considered first, does not apply in a man-of-war. Here the material is disposed relative to the strains, and so that its strength will be utilized to the fullest extent; and certain dangers to the life of a battleship, such as a shot under the water line in some unprotected part, or a torpedo attack, must be provided for by many water-tight compartments, and by a double skin. There must also be special structural provision to carry the armor and to receive the mounts of great guns; so that the hull of a man-of-war must be able not only to withstand the complicated strains due to the movement of the ship in a sea way, but must also support great weights of armor, and the shocks due to the firing of great guns. Much of our battleship's efficiency, therefore, depends upon her structural strength.

The man, like the ship, depends very much on structural strength. If he does not start out with a sound body, which is the hull that must carry all his means of offense and defense, he is apt to be worsted in the struggle of life. A good constitution for the man is, to him, what structural strength is to the man-of-war; and, if he starts in life with such a precious possession, he must be careful to preserve it.

The hull of the man-of-war, built, as it is, on the cellular principle, will deteriorate very rapidly if not properly cared for. Every part must be cleaned and painted frequently, to prevent corrosion and consequent waste. The naval architect may have provided a perfect structure, to begin with, but want of care may render all his wise provisions valueless.

The man, like the ship, is also constructed on the cellular prin-

ciple. Men of science now tell us that he has grown, by a process of evolution, from a single simple cell to his present complicated structure of living cells, and it requires the greatest care on his part to preserve this wonderfully complicated cellular structure in order. His equipment may be first class in every respect; he may have a powerful battery of all kinds of knowledge; but he cannot successfully carry it into the battle of life if he has neglected to care for his hull. If dirt has been allowed to accumulate in the bilges and double bottom of his life, corroding the whole structure of his manhood, then, when the day of battle comes, he will not be able to carry his battery into action; and that not because of any original defect or structural weakness, but because he neglected to obey the rules of the service, which require him to see to it that no part of his hull suffers from waste, other than that due to fair wear and tear.

A ship of imperfect construction, where an unskillful distribution of the material has been made, resulting either in loss of strength, or in the carrying of useless weight, may, by being well cared for, and never overloaded, outlive another ship, constructed with the utmost skill, where every pound of material has been located in its proper place, but where neglect has undone all the skill of the architect.

So a man may start in life with a defective construction of hull, his structural material poorly disposed for effective work; yet by care and good management he may outlive, and do better and more effective work than, another man who starts with a perfectly constructed hull, where every part is proportioned to its work, but where neglect, as in the case of the ship, has undone all the skill of the architect. Constant care of the structure is the price of safety in the man and in the ship.

I must now consider the second division of our subject—the qualities imparted to the man and to the ship by the things placed in them or given to them. This suggests the propelling power, and how long its source of supply will endure.

In naval language this is called the radius of action.

Propelling power and how long the source of its supply will last determine the radius of action, both for the man and for the ship.

While speed is not the most important thing to be considered in a battleship, yet it is of so much importance that as much space and as much weight as possible, without curtailing other and more important qualities, are devoted to propelling machinery and to coal bunkers.

The great displacement and moderately full lines of the battleship require large engine power for moderate speeds. First-class battleships are generally supplied with one horse power for each ton of their displacement. Cruisers are generally supplied with two or more horse power for each ton of displacement. The battleship, as a rule, however, has a larger coal capacity than the cruiser, and is therefore able to steam farther from the source of supply. The distance a battleship can steam, without receiving fresh fuel, is called her radius of action. This quality is considered, by naval men, of the first importance. If, for instance, a United States battleship and a Japanese battleship, both of the same class, were enemies, and they should both leave their home ports at the same time for a cruise on the Pacific; and should they sight each other, say 30 days thereafter, the one that had the best supply of coal left would, so far as ships went, have the best chance of victory.

Large bunker capacity and economical propelling engines are therefore of great importance in a battleship, as these are the leading features in securing a great radius of action.

The battleship may, however, leave her home port with bunkers full of good fuel, and with economical engines in first-class order; but, if the fuel is wasted in driving at full speed just to see what a wave she will make, and if forced draught is resorted to, simply to get up a little excitement on board, the discovery may be made, when the enemy is in sight, that the bunkers are empty and the propelling power useless.

In the battleship there are two kinds of coal bunkers, the reserve coal bunkers, which are situated above the protective deck—these, as a rule, would not be accessible in time of action—and the ready-service bunkers. These are on the same level with the fire rooms, and open into them, and are to be depended upon in battle. A prudent commander, in time of war, will see that the engineer keeps his ready-service bunkers well filled, so that, in case of a surprise, time will not be lost in getting coal from the reserve bunkers.

In a man, as in a man-of-war, the propelling power is of great importance, determining, as it does, his radius of action. As the propelling power is the heart of the battleship, from which she obtains life, so the man's heart is the propelling power of his life. If he be fitted with a well-balanced triple-expansion heart, and if, as he leaves his training port, the protected home harbor where he was built and fitted out, all his reserve bunkers are full of the best hand-picked fuel, and his ready-service bunkers are full of sound principles, then he need fear no enemy; but if he wastes

the precious contents of his bunkers in useless excitement, ruining his boilers by forced draught, straining his engines for the sole purpose of making a big wave in society, then the enemy may find him with empty bunkers and a weathered heart.

The naval architect, in designing the battleship, has provided, as far as possible, against any failure in the propelling power, by arranging his ship to receive twin propellers, and a complete double set of engines, alike in every respect; and the power of the ship is the combined power of the two. For the best progress, therefore, they must both work together; but, if one be disabled, the other can still do its work in propelling the ship.

The all-wise Architect, who made man, saw that it would not be safe for him to be single, so he was designed for twin screws, having a complete double set of machinery, port and starboard; that is, "male and female created He them." There they stand, side by side, in the engine room, resting on the same foundation bed; and, to get the best speed out of the man, they must work together, and in the same direction. If one goes astern and the other ahead, there will be nothing but a twisting movement in the man, and racking strains that are sure to give trouble. If one goes fast and the other slow, the man will not show his best speed; but should one be disabled, the other must do its best to land the man safely in port.

There is a great element of safety in the twin screw principle, both for men and for ships. Many a man and many a ship has managed to pull through life on the single principle; but, let anything happen with the propelling power—with the heart, as it were—and they are either among the missing, or they may be picked up at sea disabled and towed into port. Should that happen, in the case of either the man or the ship, salvage claims are likely to exceed the value of the property.

Two sets of triple-expansion engines are necessary for the battleship, in order that she may safely carry the flag as far as her fuel will last, or into battle, and hand her name down to the ages on the naval roll of honor.

Two sets of triple-expansion hearts are necessary for a complete and seaworthy man, so that he may safely meet the struggles of life, and preserve his name and honor to posterity.

Another quality, necessary both to the man and to the battleship, if they are to be serviceable, is adequate means of defense. In the man-of-war or battleship, to which I refer, the naval architect provided an armor defense of the most modern design, and required

it to be constructed of the most effective material yet invented, to resist penetration by shot from an enemy.

When shipbuilders began to build iron-clad ships of war, the armor protection was carried the full length of the ship, as it was desired to make everything about her safe; but other inventors, just as skillful as the shipbuilder, were at work on the means to penetrate the protection that had been built around the ship; and, as guns became more powerful, the armor defense had to be made thicker and heavier, until the displacement (that is, the foundation) failed to carry it; and so it came to pass that the whole length of the ship could no longer be covered by armor, even when face-hardened, which would resist an armor-piercing shell from the modern gun.

So the designer of our man-of-war adopted what is known as the citadel type, the main feature of the design being that the heavy armor protection extends only over the vital parts of the ship, protecting the engines, the boilers, the big guns forming the main battery, the intricate mechanism that operates them, and the magazines. This armor is all Harveyized or face-hardened steel, which has been proved as to its ability to resist penetration, even at short range, and by the most powerful guns.

This citadel of heavy armor is about 200 feet in length, and the armor of the lower part, or side belt, is 18 inches thick. The armor of the bulkheads, forming a parabolic curve at each end, is 14 inches thick. At each end of this structure, and rising directly above the bulkheads, is a circular redoubt or barbette, with walls 14 inches thick and 12 feet high, protecting the base of the revolving turrets, and the intricate hydraulic machinery that operates them. Above these redoubts rise the upper portions of the great revolving turrets, 35 feet in diameter, each weighing 400 tons and having armor 12 inches thick.

Above the heavy belt armor I have described, the sides are plated with 5-inch steel armor, forming a casemate for the protection of the crew and upper works against the attack of rapid-firing secondary batteries, so fatal to unprotected quarters.

Above this upper belt of armor rises the superstructure, with armored sponsons for four 6-inch guns; and, at each corner, still higher, so as to fire over the roofs of the great turrets, are mounted the four armored turrets for the 8-inch guns which proved so effective in the destruction of the Spanish fleet off Santiago.

This man-of-war of ours carries more and heavier armor than any other battleship in the world having the same displacement or foundation, and foreign naval designers have wondered how we have managed to get so much on our foundation of 10,400 tons.

In the ends of the vessel, beyond the armored citadel, there are numerous storerooms, where wet and dry provisions, all clothing and equipage, besides the personal effects of officers and crew, are carried. The rooms where the officers live, and the quarters for the crew, are also outside the armored citadel.

A man, like our man-of-war, must also have, if he is to be a true, safe and noble man, an armor-protected citadel, on which his safety will depend in time of battle. His storehouses, into which he packs his earthly belongings in ordinary times, and while cruising peacefully on the sea of life, are very necessary and convenient for his comfort in and enjoyment of life. But no man has displacement enough to carry armor protection for these. If he sets himself to protect these things, then, in time of battle, he must leave unprotected the most vital things of his life.

The true man must therefore have a citadel, within which he places his propelling power—that is, his heart; the boilers, which furnish his power of will to do the right thing and keep in the right course; his magazines of truth—those things which he must stand by—the shot and shell with which he fights every power of evil that seeks his destruction. Around these vital elements of his being, he must dispose whatever armor the great Architect has furnished him with, so that, in the day of battle, when the final test is made of his power to endure the onset of the adversary, and to stand fast, no matter what may happen in his armored citadel, the great principles which govern his life may be carried through the fight, and nothing given up to the enemy but what can be readily replaced when the battle is over.

In the battleship, even life itself is not the first thing to be considered. The life of the crew is protected by a casemate of 5-inch armor, while the vitals of the ship are protected by 12 inches of armor.

So, with a man, there should be some things that are more than life. There are the great truths that he believes and holds more sacred than life itself, and around these he will concentrate all his powers of resistance, knowing that, if he meets death and these live on, the victory is his. So, whatever power we have to resist the fire, let it be concentrated around the most precious and enduring things.

But, for a man and for a ship which have to fight their way through life, there must be means of offense as well as of defense. Hence, for the ship we have been considering, the naval architect provided a powerful battery, of both great and small guns. He also designed magazines and shell rooms, properly protected by armor, to carry a great store of ammunition, with ample means for

handling both the guns and the ammunition for serving them properly.

The great battleship, which I have had in mind throughout this lecture, has a main battery consisting of four 13-inch breech-loading rifled guns, mounted in two revolving turrets, one at each end of the armored citadel. These turrets are worked by hydraulic machinery within the armored redoubt. There are eight 8-inch breech-loading rifled guns, mounted in four revolving turrets, protected by 8-inch armor. These turrets are operated by steam machinery, placed down under the belt armor line.

There are four 6-inch guns mounted in the superstructure, and protected by 5-inch armored sponsons. These guns are trained by hand. This constitutes the main battery, which is more powerful than that carried by any other war ship on the same displacement or foundation.

The secondary battery consists of twenty 6-pounder rapid-fire guns, mounted all around the upper line of the superstructure, their position being protected by the hammock berthing; that is, a line of double walls of plate steel, between which the sailors' hammocks are packed, forming a protection against the fire of small guns.

It was for the purpose of carrying this great battery into action, and using it effectively, that this great ship was designed. All her other qualities have been devised and worked into the general design for this purpose. That battery and the armor that protects it were designed not for the wanton destruction of some poor, weak antagonist that could not return blow for blow. It was all devised by the designer to protect the honor of that flag that waves so proudly above it, and to stand for defense of the right. For this purpose the naval architect prepared his plans, balancing one force against another, working harmony out of their contending elements. The engineer, for this purpose, installed, in the center of this great structure, his mighty engines for propulsion, the beating heart of the whole. For this the ordnance expert conceived the wonderful and intricate mechanism to handle ammunition, and to operate guns and their mounts. For this purpose the electrician planned, and placed far down in the bowels of this mighty structure, the electric generators that supply the subtile fluid, the nervous system of this great machine, that gives light to the dark places, and motion to many wonderful contrivances. By it the eye of the projector is illuminated and its movements controlled, enabling the commander to pierce the gloom of the blackest night.

The optician not only planned the instruments whereby the

navigator can tell where his ship is, but a range finder also, whereby the position of the enemy can be determined.

All this and very much more are brought into play, in order that the battery and its protecting armor may be brought successfully into action, and that the cause it represents may be triumphant.

In a man, as in a man-of-war, all his qualities must be trained for the purpose of enabling him to carry his battery successfully into the battle of life. Many contending forces and antagonistic powers have to be brought to work together for the end in view.

In all our planning for a complete and efficient manhood, we must, like the naval architect, set the forces in couples against each other, taking care that the righting forces will more than balance the heeling forces, training the body—that is, our hull—to properly carry the mental battery with which it is equipped. Sacrifices must be made of many cherished possessions, or of acquired habits, to make room for more important things that cannot be left out if our battery is to be efficient in time of battle.

A man-of-war is a complicated combination of compromises, and so is a man. We can carry no more than our displacement represents, and we shall not be able to realize, in action, all that we had planned, and sacrificed for, to obtain.

But we can so carry our battery—that is, the mental caliber with which the great Architect of our being has endowed us—into the battle of life, that, however the battle may go with us, whether it be victory or defeat, it shall not be disgrace.

Having thus noticed the material elements in the man and in the ship, I may be permitted, in closing, to devote a few words to the crew complement of the ship, and to the personnel of the man.

In this lecture, I have endeavored to compare the material elements entering into the character of the man and into the structure of the ship. We have examined the foundation supporting each; the stability due to dimensions and to the height of M above G; the steadiness, due to form combined with the qualities that produce stability; the structural strength; the radius of action; the armor and armament; and we have endeavored to show how the qualities that go to make a good ship are like those that go to make a good man.

But neither a good man nor a good ship will accomplish much, unless handled by an intelligent and faithful crew that knows the power and capacity of the mechanism it is to operate. The crew of a gunboat is not expected to accomplish, with the means at its disposal, what is expected from the crew of a battleship; nor is the will power of the man who has a small displacement, with little

protecting armor and a light battery, expected to accomplish as great things as the man of strong will power—a man of great character behind strong armor, with an intellect of great caliber and magazines full of rich experience.

Yet, whatever be the size or power of either man or ship, each is expected to accomplish the purpose for which he or it was built and equipped; and this they can do only if the crew complement of the man-of-war and the personnel of the man are of the right kind.

If our man-of-war is not commanded by a brave, wise and prudent captain, who knows what kind of ship he commands, her power and capacity, with all its limitations, her best trim and best speed, what class of enemy she can meet and battle with, and how the battle must be fought if the victory is to be gained; if the executive officer has not an eye to the efficiency of all the working force of the ship, testing everything often and in all weathers, taking nothing for granted, but by personal inspection keeping, at all times, familiar with every detail, so that the hour of struggle will find everything in working order; if the navigator fails in his duty to find out every day the true position of the vessel, the position of all dangers, the force and direction of all currents; if he does not keep his course worked out ahead and plotted on the chart for guidance; if the watch officers do not keep their eyes open for every danger that surrounds them, that no lurking torpedo boat gets near enough to discharge its deadly weapon, or enemy get within range without the captain's knowledge; if the engineers fail to keep in perfect order all the machinery under their care, so that any sudden call for the best that such machinery can do can be responded to; if the ordnance officer has neglected to see that all the mechanism for training, elevating and controlling the guns is in good order, that the ammunition hoists are operative, that his telescope sights, range finders, battle-order transmitters, and all other things on which so much depends in action, are all as they ought to be; if the doctor neglects the health of the crew, and if, in consequence, they become inefficient—then, in the hour of battle, our well-planned, strongly built, magnificently equipped battleship will be found wanting; all the talent expended in its production will be lost, and the flag that it carries disgraced, because the power that willed to do failed.

As it is with the man-of-war, so it is with the man. If the will in command be weak, cowardly, or vacillating; if it either fails to order aright, or orders at the wrong time; if the executive force that carries the will power into execution cannot be depended upon when he knows the right thing to do; if the navigator's skill

is so defective that the man never knows where he is, or what dangers surround him, or from which side the enemy is likely to attack him; if he goes through life in an aimless sort of way, with no watch on deck to keep him warned of danger; if his machinery is neglected; if his affections are all adrift, with no center for his heart to work upon; if he cannot respond to a call for a supreme effort in time of battle; if his ordnance, with all its delicate mechanism for training his best thoughts against the powers of evil, is inoperative through want of practice; if he has taken no care of his health; if he has contracted habits destructive of discipline and all proper management of himself—then, no matter how well he was planned and equipped, his record in life will be a failure.

The great Architect planned and equipped this wonderful organism of ours, with its vast possibilities, placing us in command, having the freedom of our own wills, and launched us out on the sea of life, amid dangers and storms, with enemies on all sides, and yet with powers of offense and defense sufficient to carry us triumphantly through every struggle. Let us but be faithful to our high calling, and see to it that whatever power we possess shall be kept in good working order and ready for action; that none of it shall be squandered in idleness and self-gratification; that, be our power or influence great or small, it shall be expended for the purpose of setting wrong things right and making crooked things straight and sad hearts happy.

Only this kind of use, made of our lives, will give us satisfaction and please the great Architect who planned us.

OBITUARY.

George H. Wallis.

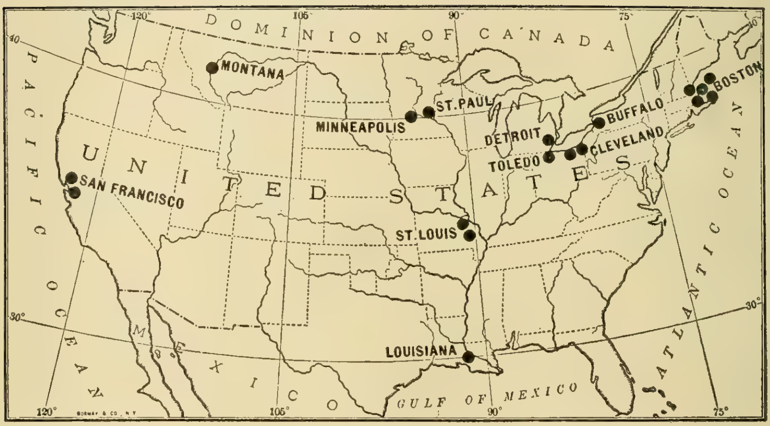
MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

On Sunday, March 19, 1905, death called from us one of the prominent members of the Technical Society of the Pacific Coast, Colonel George H. Wallis, one of its directors, who had served faithfully for several terms in this capacity. He was stricken down suddenly while reading a newspaper after breakfast, apparently in good health and in excellent spirits. He was 68 years old.

Colonel Wallis was a veteran of the Civil War, a member of George H. Thomas Post of San Francisco, from the hall of which he was buried on Tuesday, March 21st, with military honors. In his civil capacity he was the chief engineer of the American Steel and Wire Works, with headquarters at San Francisco. He was a man of great mechanical skill, of sound judgment and of very clear-headed business sagacity. No one was better liked than Colonel Wallis for his gentle, genial manner and his ever-ready courtesy, so manifest a characteristic of the true type of the educated gentleman of the old school.

The Technical Society of the Pacifie Coast feels this loss keenly, and will prepare suitable resolutions in memory of its friend and counselor.

OTTO VON GELDERN, *Secretary.*



MAP

Showing the locations of the Societies forming

THE ASSOCIATION OF ENGINEERING SOCIETIES.

(Each dot represents a membership of one hundred, or fraction thereof over fifty.)

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Organized 1881.

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THE PRESERVATION OF TIMBER WITH ANTISEPTICS.

BY E. H. BOWSER, MEMBER LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, November 14, 1904.*]

WHILE there are facts indicating that efforts were made to prolong the life of the timber used in structural work, by means of antiseptics, as early as 400 B.C., still, so far as we know, no very satisfactory results were obtained until the decade between 1830 and 1840. Many of the processes which came into use at that time, though somewhat effective, have practically been abandoned.

The only preservatives that have stood the test of time and that are used to any great extent at present are chloride of zinc and dead oil of coal tar, the latter commonly called creosote oil, though it contains no true creosote.

The chloride of zinc treatment is not nearly so common in this country as creosoting, and it is used almost solely for the preservation of cross ties. This treatment is not very effective, except when the timber is kept comparatively dry, as the chloride is very soluble in water and will soon leach out in a damp climate, or when placed in water. It is of no value whatsoever for the protection of timber or piles against marine worms.

This chloride was first brought into extensive use by Sir William Burnett in 1838, and it has from that time until the present been more or less used. On account of the man who promoted its use, the process is known as Burnettizing. Ordinarily, the solution for this process is composed of $2\frac{1}{2}$ per cent.

* Manuscript received March 31, 1905. — Secretary, Ass'n of Eng. Socs.

of zinc chloride and 97½ per cent. of water. One of the principal recommendations for the use of this process is its cheapness.

The zinc solution is often combined with other substances with the object of preventing the chloride from being affected by moisture. In the Wellhouse process the chloride is mixed with the usual amount of water and creosote oil is added to this mixture. In the Allerdyce process the timber is first treated with the chloride of zinc solution and then, after letting it dry for a few days, or, without taking the Burnettized timber from the cylinder, it is treated with about 3 lbs. of creosote oil. The theory is that the outer pores of the wood are filled with the creosote oil and this keeps the moisture from coming in contact with the chloride.

Another method of zinc treatment which is used to a considerable extent by the Mexican Central Railroad at Aguas Calientes, in Mexico, is the zinc-tannin-glue process. The timber is first treated with the chloride of zinc, the liquid is then drawn off, and a weak solution of glue is run into the cylinder; when this is drawn off a solution of tannin is put in. The theory of this process is that the glue gets into the outer portion of the wood, and the tannin hardens the glue, making it insoluble in water.

The bichloride of mercury, also called corrosive sublimate, and sulphate of zinc were formerly used for preserving wood, but the former is used very seldom, and the latter probably not at all. The worst feature of any of the metallic salts that have been used for preservative purposes is their solubility in water, which decreases their effectiveness very much when the treated timber is buried in damp ground or exposed to the action of the weather. Of course, none of these salts are at all effective when the timber is placed directly in the water.

The first authentic record we have of the use of creosote oil for the impregnation of timber in order to preserve it from decay is in 1756, though the value of rosin, tar and pitch was known in ancient times.

It was not, however, until John Bethell of England invented the process of injecting oils or other liquids into timber that creosoting was placed upon a practical basis. From that time until the present, the creosoting process has been constantly gaining favor and is universally recognized as being by far the best process for the preservation of timber, in the earth, in the water, or in the air, and it is the only process that is effective against the destruction of timber by the Teredo navalis, or other marine worms, and insects. For the benefit of some of

you who may never have visited a creosoting plant, I will explain the present method of creosoting, as done in this country, and give an idea of the appliances used.

For simplicity, we will take a one-cylinder plant. A common size of cylinder is 6 ft. diameter and 100 ft. long. There are, however, several cylinders in this country 9 ft. in diameter, and one of these, located in New Orleans, is 172 ft. long, and, I think, is the largest creosoting cylinder in the world. A 6-ft. cylinder should be made of flange steel five-eighths of an inch thick, with horizontal seams triple riveted, and girth seams double riveted. The lengths of the rings are usually 6 ft., one sheet of metal making the entire ring. The cylinder is mounted upon supports about 2 ft. above the floor so as to allow for pipe connections underneath. The ends are sealed by hinged doors, generally made by riveting hemispherical boiler-plate heads on cast flanges, though probably a better door is made of cast steel slightly convexed and ribbed. The doors for a 6-ft. cylinder are fastened by 36 bolts 2 in. in diameter. There is a circular ridge on the face of the door flange 2 in. wide and $\frac{1}{4}$ in. high, which fits into a corresponding groove, on the face of the cylinder flange, three-eighths of an inch in depth. Cotton or asbestos webbing is placed in the groove so that when the door is closed and bolted it is steam tight.

In the bottom of the cylinder is a track upon which the trucks loaded with timber are run. Between the rails of this track are from 12 to 18 1-in. steam pipes, extending from one end of the cylinder to the other. Often there are steam pipes on the sides just below the center of the cylinder. These pipes are connected at the ends with return bends and coupled to a steam pipe from the boiler. The heating pipes should be divided into three or four disconnected groups, causing less condensation of steam than would occur through a long series of pipes and allowing any one or two of the groups to be cut off should a leak occur during the process of treatment.

A leaky pipe can be very easily detected when the steam or oil pressure is on, by the leakage of the steam or oil through the open end of the pipe. When steam is passed through the coils for heating timber during the vacuum or heating the oil when it is in the cylinder, the coils should be open at the exit end during the vacuum and open or slightly throttled during the injection of oil.

Connected with the cylinder from the bottom, generally near the middle, there should be a 6-in. suction pipe leading to the vacuum pump.

At the top of the cylinder there should be a 3-in. pipe which leads to the discharge end of the oil pump, the suction end of this pump being connected by a 4-in. pipe with the measuring tank.

Between the measuring tank and the cylinder there should be a 10-in. pipe connection and also the same size pipe between the cylinder and the underground or dumping tank. These pipes can be connected just before entering the cylinder to save an extra opening.

For supplying steam to the cylinder there is a 2-in. pipe which is coupled at the shell of the cylinder to a 1-in. pipe which lies along the heating pipe coils, the 1-in. pipe being perforated with small holes throughout its length to dissipate the steam when it is turned into the cylinder upon the timber. The heating coils are also attached to the 2-in. pipe.

Finally, there is a vertical pipe of from 4 to 6 in. in diameter leading from the top of the cylinder through the roof. This is a blow-off pipe for letting out the steam after the timber has been steamed sufficiently. All of the pipes are, of course, supplied with the proper cut-off and check valves.

Upon the bulkheads at the ends of the cylinders are laid tracks upon which the trucks are loaded. At one end of the cylinder the untreated timber is loaded on the trucks and at the other end it is unloaded after it is treated. The side where the timber is loaded is usually called the "white side" and where it is unloaded, the "black side."

The measuring tank is usually about 20 ft. in diameter and from 20 to 25 ft. high, and rests on a tank frame 12 to 14 ft. above the ground. The oil in the measuring tank is kept hot by means of 1-in. steam pipe coils inside of the tank. These pipes are hung vertically in pairs coupled at the bottom with return bends and hanging at intervals of about 5 ft. The tank is supplied with a float and gage so that the depth of oil in tank is always shown.

The underground or dumping tank is usually of the same capacity as the cylinder. It should be buried deeply enough in the ground to be covered with sufficient earth to prevent it from floating up when empty, if there is water in the ground. The dumping tank and other storage tanks used should have heating coils, as in cool weather more than 50 per cent. of creosote oil, containing the amount of naphthalene ordinarily specified in contracts, is more or less solid.

A pump is needed between the dumping tank and the measuring tank so that the oil can be returned to the latter tank

after a treatment is made. In a two-cylinder plant this pump should be of large capacity to prevent delay.

Oil received in tank cars or barrels can be dumped directly into the underground tank and then transferred by means of the pump into the measuring tank or storage tanks. There should be a derrick or traveling crane at each end of the works for loading and unloading the trucks.

The most economical handling of the material is, of course, where it can be unloaded directly from cars to the trucks and after treatment unloaded from the trucks and put directly on cars for shipment.

For pulling the train of loaded trucks into and out of the cylinder a hoisting engine is used, with proper ropes, cables and blocks.

The complete process of treatment used almost universally in this country at the present time is as follows:

The timber is loaded on the trucks and drawn into the cylinder by means of a wire cable which is fastened to the rear end of the load, and passes under the trucks, and around the sheaves at the end of the unloading track to blocks and tackle, the fall line of which is fixed to the drum of the hoisting engine. The cable has a coupling near the front end of the load and the part lying under the load is left in the cylinder. As soon as the doors are closed and bolted, the steam is turned into the cylinder and kept there under the required pressure for from ten to eighteen hours, according to the amount of oil required.

The treatment under consideration is supposed to be of freshly sawed timber and not seasoned at all. Seasoned timber requires no steaming.

The steam is turned off at the proper time and the condensed water in the bottom of the cylinder is blown out before the steam is exhausted through the pipe at the top.

When the steam is all out the vacuum pump is started and kept going for from five to eight hours, the vacuum being brought as quickly as possible to a gage reading of from 22 to 24 in. During this process steam is passed through the heating coils.

When the vacuum pump is stopped the oil, heated as hot as it can be gotten by steam pipe coils containing steam under little or no pressure, is admitted into the cylinder and as soon as it is full a reading of the tank gage is taken, and the pressure pump is started. When the pressure gage registers about 150 lbs. the pump is generally held at that until the timber has

received, according to the gage, the proper amount of oil. The oil is then dumped into the underground tank and pumped back into the measuring tank. The difference in the reading of the tank gage before the oil is put into the cylinder and after it is pumped back into the measuring tank, gives the exact amount of oil injected into the timber. This can never be gotten exactly till after the treatment is completed, as during the filling of the cylinder, the pores of the wood being under a vacuum, some oil is absorbed and, of course, the amount of this absorption is not shown on the gage readings between the filling of the cylinder and the completion of the treatment. This absorption will sometimes amount to as much as 2 or 3 lbs. per cu. ft.

The theory of this process is that the steam opens the pores of the wood and liquefies the sap. The heat in the coils during the vacuum vaporizes the moisture in the wood and this vapor is taken off by the vacuum pump. The vacuum being in the wood when the oil is admitted draws more or less oil into the pores and the pressure from the pump forces in the remainder of the oil required. If dry heat could be used in the heating coils and in the cylinder, and the treatment by that method would require no longer time, it would be a vast improvement over the present method. The great trouble would be in obtaining the heated air as cheaply and in regulating the temperature as exactly as can be done with steam.

Timber can be injured by being subjected to too high a temperature in steaming. I would recommend the following steam gage pressure for steaming timber and piles:

Least dimension 3 in. or less	30 lbs.
,, ,, 6 in. to 8 in.	35 lbs.
,, ,, 8 in. and more	40 lbs.
Piles for teredo water	50 lbs.

I do not think that the temperature due to these pressures, when applied for the length of time usually employed in creosoting, will injure the timber in the least. For teredo water I think the steam pressure shown for piles in teredo water is better than a lower temperature.

While the treatment of timber with creosote oil has been widely practiced for more than sixty years, no absolutely definite decision has been reached as to the best kind of oil to be used for this purpose. Creosote oils differ considerably in their constituent parts and it has never been fully decided what proportion of these constituents the best oil should have. Until

recently the greater number of experts on creosoting have considered that naphthalene was the most important constituent in the oil, and nearly all of the specifications in this country stated that there should not be less than 40 per cent. of naphthalene in the oil. Lately, however, many of them are advocating a preponderance of the heavy oils beyond naphthalene in the distillation, and consider the latter substance of no importance whatsoever. This is largely due to the fact that naphthalene, though insoluble in water, vaporizes at all temperatures, and it is claimed by parties who have made tests with specimens of treated timber that in time all of it passes from the wood. Whether this is correct or not, the experience of the Louisville & Nashville Railroad Company shows that oil with a large amount of naphthalene in it is good oil for the preservation of timber both from decay and from the teredo, when the material is well treated. I am, however, of the opinion that the heavy oils are preferable to the naphthalene though I do not think it has been proven beyond a doubt. The great trouble is that it takes thirty years to properly test a preservative. Outside of its use in creosote oil, about the only commercial value of naphthalene is for manufacturing moth balls, and as the manufacturers of creosote oil naturally wish to get rid of their naphthalene, and moth balls give them a very small market, possibly this fact has had considerable influence in making it prominent as the principal preservative in the oil.

I have received oil from the foreign market that had as much as 75 per cent. of naphthalene, and it was solid in the barrels in warm weather. It was impossible to give good treatment with this oil as it could not be gotten thin enough with steam heat to penetrate the wood, and it had to be mixed with lighter oil before it could be used.

The ordinary analysis of creosote oil is by simple distillation, it being necessary to use reagents only when the amount of tar acids in the oil is to be determined. To make this distillation, an ordinary 200-gm. glass retort is used and the heat applied by a Bunsen burner or a special laboratory lamp where gas cannot be obtained. The products of distillation are collected in the test tubes in the usual way and the percentages determined by weight. One distillation is all that is required, but a second distillation will, of course, give more refined results. I give below the products that come off at different temperatures, a centigrade thermometer being used:

Up to 170°	water, hydrocarbons and phenols	liquid
170° to 205°	phenols and creosols	solid and liquid
205° to 210°	phenols, creosols and naphthalene	solid
210° to 235°	naphthalene, chiefly	solid
235° to 240°	naphthalene and anthracene	solid
240° to 270°	anthracene oil	liquid
270° to 316°	anthracene oil and anthracene	solid and liquid
316° plus	pitch	solid

An analysis of oil from the Barrett Manufacturing Company, made in 1899, is as follows:

85° to 170°	1.4
170° to 205°	7.7
205° to 210°	7.3
210° to 235°	53.8
235° to 240°	5.0
240° to 270°	9.4
270° to 316°	3.5
316° plus	11.3
Loss	.6
	100.0

This oil at the time it was used was considered to be fine oil for creosoting purposes. With the large amount of naphthalene in this it would require all of the light liquids shown to make it thin enough to enter the wood. It would, however, have been a better oil if it had a little less light liquid, less naphthalene and more heavy oil beyond 260°. Here is an analysis of a sample of Scotch oil made the first part of this year:

Up to 170°	7.48
170° to 205°	9.91
205° to 245°	44.03
245° to 270°	14.03
270° to 320°	12.36
320° to 420°	3.80
Residue	8.39
	100.00

Specific gravity, 1.028 at 40° C. Tar acids by volume, 12.25 per cent. According to the old standard for oil in this country there is too much distillate up to 205° and too little between 205° and 245°. The remainder of the distillate would have been very satisfactory as there is somewhat more than 25 per cent. above 260°.

The lack of naphthalene and too much light liquid gives a low specific gravity. If the distillation shows the oil to be good

the specific gravity will always be right. Taking into consideration its preservative qualities and also the extra expense of using an oil that differs very much from the natural product of the works from which creosote oil is obtained, I would recommend the following specifications for oil:

> "Water to the extent of 2½ per cent. shall be allowed in the oil without compensation. Any amount of water over 2½ per cent. and up to 8 per cent. shall be compensated for by the injection of a proportionately greater quantity into the timber. No oil containing more than 8 per cent. of water shall be used. The specific gravity shall not be less than 1.04 at a temperature of 35° C. It must not yield more than 10 per cent. of its weight by distillation up to 210° C. Between 210° C. and 235° C. the distillate shall not exceed 30 per cent. by weight, nor shall be less than 25 per cent. At least 30 per cent. shall not distill until after 260° C. has been reached. The thermometer is to be kept about one-eighth of an inch from the oil during distillation."

I am sure these specifications would give an oil that would be satisfactory for all purposes and would last either in teredo water or in any other situation.

Any wide departure from the natural by-product of the distillers, of the residual liquids from gas works and coke retorts, would increase the expense of the oil very materially by the extra manipulation and the reduction of the natural output by the wasting of some of the constituents of the oil.

The supply of creosote oil does not always equal the demand. Four years ago the chief engineer of the Louisville & Nashville Railroad was paying as high as 12½ cents a gallon for oil and could not get it as fast as needed. The price just previous to that time was six cents per gallon. If all the creosoting works had been in full operation this year the available supply would have been exhausted by the middle of the year if it had been evenly distributed. At the first of this year, just before the railroads began to cut down expenses on account of lack of traffic, there was only 300,000 gals. offered in this country for delivery during this year, and practically none was for sale in England, where nearly all of the foreign oil in this country is purchased.

The distillation of slack coal from the mines is becoming an industry in this country, but it is receiving somewhat of a check from the fact that some of the ore-smelting operators claim that the coke obtained is not so good for their purpose as that made in open coke ovens. Without the sale of the coke, the distillation of coal for other products would be unprofitable.

As to the lasting qualities of creosoted timber, every engineer knows that it has been fully demonstrated.

Some very fine specimens of creosoted work can be found on the line of the Louisville & Nashville Railroad, between Scranton and New Orleans. Large numbers of piles in the bridge piers on this line are in teredo water, have been there more than 28 yrs., and are still in a perfect state of preservation. Many of these piles are in places where they would be unsafe in 3 mos. if put in the water at the beginning of the teredo season. Recently in rebuilding these bridges it became necessary to cut off a few feet from the ends of the piles to get them low enough for the new superstructure, and nearly all of them were in as good condition as the day they were driven. The few that had been affected had been broken or split by collision from boats, or by coming in contact with floating timber or drift wood during storms.

In the Louisville & Nashville Railroad wharves in Pensacola Bay there are a great many creosoted piles driven 23 yrs. ago which are still in use and in good condition.

About as satisfactory a record as I know of, is that of a long line of telegraph poles in England which were treated with only 8 lbs. of oil per cu. ft., and from a thorough examination after they had been in use for 30 yrs. *not a single one of them* was found to be affected by decay. These poles were naturally seasoned before treatment. This, no doubt, gave slightly better results than steaming would have done. Ordinarily 12 lbs. of oil per cu. ft. are used for telegraph poles, though sometimes only 10 lbs. are used.

At West Pascagoula, Miss., before the burning of the creosoting works last year, there was a telegraph pole treated in 1877 which was in a perfect state of preservation. Unfortunately, it was burned down to the ground at the time of the fire. I judge from the appearances that this pole was treated with more oil than is generally used for this class of work.

In this section pine is the only wood used for creosoting, and, with the exception of the lower grades of oak for cross ties, pine is used universally in all parts of the United States for this purpose.

I give below a schedule showing the proper amount of oil per cu. ft. to be put into timber used for different purposes:

Foundation timbers and lower floor joists for buildings,
fence posts and cross ties .... 10 lbs.

Bridge, wharf and culvert timbers natural and sawed telegraph poles, cross-arms and wooden ducts for electric wires	12 lbs.
Piles for interior work	16 lbs.
Sawed timber for teredo water	18 lbs.
Paving blocks	20 lbs.
Piles for teredo water, as much as can be put into the timber, in no case less than	22 lbs.

There is not the least doubt that well-creosoted timber will last considerably longer than 30 yrs., and I venture to say that a heavily treated sap-wood pole would last at least 60 yrs., and, possibly 100 yrs., if not destroyed by other agents than decay. An untreated sap pole would begin to decay at the ground in about six months, and would generally be rotted through and through in two years.

It must be borne constantly in mind, however, that to be thoroughly effective, creosoting must be well done. This is an all-important point about creosoting work, and it is a thing that can be very easily slighted by the carelessness of an inspector, or the carelessness or culpability of the operators of a creosoting plant.

Parties having creosoting work done must depend more or less upon the honesty of the contractors doing the work, even if there are a dozen inspectors employed who thoroughly understand the process of treatment. No one knows exactly what is going on in the cylinder, no matter how closely he watches it. Sometimes accidents will occur that will cause bad treatment without the operator finding it out.

I have the record of one load which turned out bad, while I was superintendent at the West Pascagoula Works. This was sheathing for a dredge boat. In one year the teredos completely riddled about two-thirds of this sheathing. Either through the carelessness of the engineer in charge at the time, or through some accident, the proper amount of oil did not get into the lumber, but I could not trace the cause. Of course, such occurrences as these are comparatively rare. Unless work is intentionally slighted for profit, it can be done properly by any one who understands the work, but it requires very close and constant attention to details.

Good oil in one treatment may be bad oil in a succeeding one. For instance, the breaking of one of the pipe coils in the measuring or the underground tank may, in a very short time, put a great deal more water into the oil than good treatment will allow. To get the best results a test should be made for

water before every treatment, and the sample should be taken from the pipe through which the cylinder is filled and drawn continuously during the filling. Occasionally a sample should be taken from the discharge pipe of the oil pump when the oil has nearly all been injected in the timber. In the measuring tank most of the water is in the upper portion of the oil, but it would hardly be fair to test an average sample from the measuring tank, as the oil is drawn from the bottom of the tank, and if the measuring tank has two cylinder loads in it, the upper half of the oil will contain a very much larger proportion ot water than the lower half.

At the first creosoting works of which I took charge, I found there was too much water in the oil, and, after investigation, found that no steam came from the exit of the steam coils in the measuring tank, the throttle being nearly wide open at the other end where the steam entered. This, of course, meant a broken pipe. All of the steam that went into the oil was condensed.

At another works I found 30 per cent. of water in the oil, and pumped out about 10,000 gals. of water on the ground. This water contained about 10 per cent. of oil. At one time during my management I failed, for a short period, to personally analyze the oil being used, and an inspector making an analysis found 17 per cent. of water in one of the tanks from which we were using oil. There was not, however, a large quantity affected. I mention these incidents so show how easy it is to get water in oil even when it is not the intention of the operator to let water accumulate. The most difficult feature in operating works of this kind is to keep the water out of the oil, and any one who can invent a suitable process that will do away with the direct use of steam in the cylinder and coils, will do a great work in the advancement of the preservation of timber by means of creosote oil.

THE STRENGTH OF CONCRETE.*

By Sanford E. Thompson, Member Boston Society of Civil Engineers.

[Read before the Society, September 21, 1904.]

The data which the speaker has to present to you to-night deal chiefly with the strength of plain concrete, that is, concrete without reinforcing steel. The widespread interest in reinforced concrete is appreciated and will be referred to before closing. It is hoped that it will be included also in the general discussion to follow these remarks. However, in the design and construction of reinforced concrete, the concrete itself plays a rôle as important as does the steel, and the variation of the strength of this material under different conditions has been overlooked sometimes in the theoretical study of the combination of concrete and steel.

As an illustration of the part which the concrete plays in reinforced beams, we may refer to the recent experiments upon reinforced concrete by Professor Hatt and by Professor Talbot. One of the principal objects sought in the tests made by these gentlemen was the determination of the location of the neutral axis. Professor Hatt found the neutral axis to be located at a distance below the most compressed fiber, varying with the location and percentage of steel from 0.36 to 0.43 of the depth of the steel. That is, for a beam whose steel is one foot below the surface and which is tested with a superimposed load, the location of the neutral axis would vary from 0.36 to 0.43 feet below the upper surface. Professor Talbot, who employed a very large range of percentages and types of steel, found a ratio varying with the conditions from 0.31 to 0.56. If the location of Professor Talbot's neutral axis is calculated, using the same constant which must be used for Professor Hatt's, there will be found no agreement whatever.

The real cause for this disagreement must be determined by further experiments, but studies which the speaker has made of the tests convince him that the difference is due primarily to the character of the concrete. Professor Hatt's compressive

* Many of the tables and diagrams in this paper, together with portions of the text, are quoted from Taylor and Thompson's book entitled "Concrete, Plain and Reinforced," copyrighted by Frederick W. Taylor, 1905, and with whose permission for the purposes of this paper such quotations have been made.

tests of plain concrete showed a modulus of elasticity of about 4,000,000, which, using 30,000,000 as the modulus of steel, gives the ratio of the modulus of steel to concrete of 7.5. A ratio of 8, in the ordinary formulas for the location of the neutral axis of reinforced concrete beams, where tension in the concrete is not considered, gives theoretical results nearly identical with the actual. Professor Hatt used proportions 1 : 2 : 4 for his concrete. Professor Talbot, on the other hand, used proportions 1 : 3 : 6 based on loose measurement of cement, which makes the mixture about 10 per cent. leaner than when proportioned by a unit of 100 lbs. cement to a cubic foot. Now, in order by calculation to reach ratios for the neutral axis similar to Professor Talbot's recorded values, it is necessary to take the ratio of modulus of steel to modulus of concrete as 20, which represents a modulus of elasticity in compression of 1,500,000. Using this ratio of 20, the calculated location of the neutral axis is very close to the location as actually measured. These tests may again be mentioned, having been referred to now merely to show the necessity for a very complete study of the concrete itself. The comparative compressive strength of concrete mixed in various proportions and under different conditions is of no less importance than its modulus of elasticity, since the percentage of steel for a reinforced beam should be governed by the strength of the concrete in compression.

Leaving, then, for the present, the combination of concrete and steel, let us take up some of the practical tests which have been made upon concrete and the laws which appear to govern the strength. Since the strength of concrete is in many cases determined by the strength of the mortar, the latter must also be considered.

Laws of Strength. — At the start the points which the speaker wishes to bring out will be briefly summarized.

The strength of mortar is governed primarily by two fundamental laws:

(1) With the same sand and the same brand of cement, the strongest and most water-tight mortar is that which contains the largest percentage of cement in a unit volume of the mortar after it is in place. In other words, the strength of the mortar increases with the amount of the cement per cubic yard of compacted mortar.

(2) With the same percentage of cement in a given volume of mortar, the strongest, and usually the most water-tight

mortar is that which has the greatest density, that is, which contains the lowest percentage of air plus water voids.

The strength of concrete has not been studied so fully, but sufficient tests are on record to prove also the general application of these two laws to this material.

By these two laws, when applied to mortar, are explained

(*a*) The greater strength of a mortar containing coarse sand over one containing fine sand.

(*b*) The advantage of mixed sand in certain cases.

(*c*) The fact that the sharpness of the sand is of little importance.

(*d*) The actual benefit in certain cases of a small admixture of clay or loam and the deleterious effect of these substances under other circumstances.

Testing the Aggregate. — But one of the most practical values of these laws is shown in their application to tests of the inert material or aggregates (using this term in its broad sense to include sand as well as coarse material) for mortar and concrete. Make, for example, mixtures, in the proportion required, of cement and each of the several dried aggregates of similar texture which are submitted for comparison, add water to bring them to a uniform plastic consistency, and *the best aggregate will be that which produces the smallest volume of mortar or concrete.*

Beside discussing these facts, however, other data will be briefly presented relating to the growth of strength of concrete, the effect of consistency upon the strength (this based upon our own experiments), and the effect of different aggregates upon the strength of concrete, for example: broken stone versus gravel, large versus small stone, and hard versus soft stone.

Relation of Density to Strength.— Taking first the strength and composition of mortars, we are fortunate in having the benefit of the very thorough researches, with which no doubt many of you are familiar, of Mr. R. Feret of France, published in his paper on the density of mortar in the *Annales des Ponts et Chaussées*, 1892, in another paper in *Le Bulletin de la Société pour d'Encouragement de l'Industrie Nationale*, 1897, and in his book entitled "Chimie Appliquée." Mr. Feret's conclusions, many of which the speaker has checked by experiment, may be made the basis for practical application in the selection of materials and in design.

In the paper in the *Bulletin*, referred to, is given a complete table of mortar tests, a few of which have been chosen

by the speaker and the values converted into English units in Table I.

TABLE I.

FERET'S TESTS OF DENSITY AND STRENGTH OF MORTARS MADE WITH DIFFERENT SANDS.

Sand.	Proportions by Weight.	Absolute Volume Cement.	Density $(c+s)$.	Shearing, lbs. per square inch.	Tension, lbs. per square inch.	Compression, lbs. per square inch.
G	1 : 3.2	0.155	0.760	2,560	367	4,170
	1 : 2.5	0.186	0.745	2,790	421	5,210
	1 : 1.8	0.226	0.725	3,580	480	5,970
S	1 : 3.1	0.148	0.703	1,810	320	2,720
	1 : 2.5	0.173	0.698	2,250	368	3,430
	1 : 2.0	0.204	0.690	2,650	415	4,380
D	1 : 3.5	0.118	0.603	768	214	1,230
	1 : 2.4	0.159	0.603	1,410	302	1,940
	1 : 1.8	0.195	0.604	2,130	364	2,840
M	1 : 3.0	0.150	0.689	3,100	450	4,010
C	1 : 0	0.534	0.534	3,680	698	8,040

NOTE:

Sand G consists of granitic particles, large and rounded.
Sand S is shelly, with medium-sized grains.
Sand D is from off the dunes, strongly siliceous, fine and rounded.
Sand M is ground quartz, with angular grains of three sizes artificially mixed in equal parts.
C is neat cement.

The proportions of cement to sand by weight are similar in the four mortars selected, but the compressive strength in the 1 : 1.8 mortars, for example, varies from 2,840 pounds per square inch in the mortar with fine sand to 5,970 pounds per square inch in the mortar with coarse sand. It is noticeable that the density * in column 4 differs widely, although the proportions of the original mix are nearly identical. The cement also in the final mortar, column 3, instead of agreeing with the proportions in the dry mixture, varies with the character of the sand. In the 1 : 1.8 mortars, for example, absolute volumes vary from 0.195 to 0.226, that is, from 19.5 per cent. to 22.6 per cent. of the solid measurement.

The density of the mortar with coarse sand, G, being one-fifth greater than that with the fine sand, D, it follows that the bulk of mortar, — which is in inverse ratio to the density, —

*The term density is defined and illustrated in succeeding paragraphs.

produced with the fine sand, is one-fifth greater than that produced with the same weight of coarse sand mixed with cement in like proportions. *It is thus evident that a given weight of fine sand with a given weight of cement produces a larger bulk of mortar than the same weight of a coarse sand and the same weight of cement.* The truth of this proposition the speaker has proved over and over again by experiment. The fact, as will be brought out further on, is of the greatest importance in comparing the value of different aggregates for mortar and concrete.

The density (*compacité*) of a mortar is represented by the total volume of the solid particles — exclusive of the water and the voids — entering into a unit volume of fresh mortar.*

The "elementary volumes" in a unit volume of fresh mortar consist of the absolute volumes of the cement, sand, water and voids, each expressed in the form of a decimal. To illustrate, the "elementary volumetric composition" of the mortar in item 3 of Table I., which is mixed in proportions 1 lb. cement to 1.8 lbs. of natural sand, is:

Cement	(c)	$= 0.226$
Sand	(s)	$= 0.499$
Water	(w)	$= 0.234$
Air voids	(v)	$= 0.041$
Total volume		$= 1.000$

Expressing this in more familiar terms, 22.6 per cent. of the unit volume of the given mortar consists of solid particles of cement, 49.9 per cent. of particles of sand, 23.4 per cent. of water, and the remaining 4.1 per cent. of air voids.

The porosity, represented by the sum of the water and air voids, is 27.5 per cent. The term *voids* is often employed to represent the porosity, that is, the sum of the air and water.

It is obvious that

$$c + s + w + v = 1;$$

also that

$$v = 1 - (c + s + w),$$

which is equivalent to the statement that the entrained air in any volume of fresh mortar is equal to the measured volume of the mortar minus the space occupied by the cement, sand and water.

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* If the word density is applied to sand alone, it means the proportion of the measured volume of the sand, which is occupied by the solid sand grains; a sand, for example, having under certain conditions 40 per cent. voids, would have a density of $1.00 - 0.40 = 0.60$.

Method of Determining Density.— The density of the mortar considered is $c + s$, or, $0.226 + 0.499 = 0.725$, as given in column 3 of the table.

A thorough understanding of the use of these symbols is essential to the study of strength of concrete and mortar, for practical tests of strength are of small value unless the density and exact mechanical composition of the specimens are clearly defined.

The method adopted by the speaker of obtaining the density and volumetric composition of a mortar * gives opportunity to study different aggregates and proportions as well as the effect of variable quantities of water upon the same dry materials. It is applicable also to concrete experiments. For mortar experiments, glass tubes, such as 300 cc. graduates, or deep molds may be used for measuring the volumes. For concrete a piece of 6-inch or 8-inch pipe is convenient. The volume of mortar and concrete of dry consistency will measure the same after setting as when green, but wet mixtures may be measured before setting, and again after they have become sufficiently hard to expel the surplus water. The measurement before setting is necessary in order to calculate the volume of air bubbles entrained in the wet mortar or concrete. The volume after setting, or partially setting, however, is the only one of real importance for studying the characteristics of strength, permeability and cost. The sand is dried, or its moisture is determined by weighing and drying a sample of it. If stone of a porous nature is used, the pores of its particles should be filled with water, but there should be no perceptible moisture on their surfaces. The quantities of dry materials for a single tube or mold are weighed in the required proportions, mixed with a known weight of water, and placed compactly in the mold, whose lateral dimensions have been exactly measured so that the volume of mortar

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* The French Commission determine the "yield" of a mortar by measuring its volume green, that is, just after introduction into the molds, when an excess of water may affect the volume, and thus give misleading results with very wet mixtures.

In his report to the French Commission, 1895, Vol. IV., p. 243, Mr. Feret also measures the mortar wet, but he employs a vessel of known capacity, — a cylindrical measure whose height and interior diameter are each about 8 centimeters, — and uses only a portion of the mortar which he mixes, calculating his percentages by ratio of the weight of mortar made to the weight of mortar introduced into the measure to fill it exactly. This method eliminates inaccuracies in measuring the level of the surface.

in it may be obtained by measuring down from the top. The exact space occupied by the particles of each of the solid materials and by the water is calculated, if the metric system is employed, by dividing their total weight by the specific gravity of each, or, if English units are used, by dividing the weight times 1,728 (the number of cubic inches in a cubic foot) by the specific gravity multiplied by the weight of a cubic foot of water. After partially setting, the exact depth of the mortar in the mold is measured and its volume calculated. The percentage of each of the dry materials, which really determines the density, — which is represented by the sum of the absolute volumes of the dry material, — is found by dividing the absolute volume of each material by the total volume of the set mortar or concrete.

The specific gravity of cement which has been stored for a short time may be taken at 3.10, and the specific gravity of dry sand at 2.65.

The following example from the speaker's note book illustrates the method of finding the density when the measurements are in English weights and measures:

Example. — Find density of a mortar composed of Newburyport sand and Portland cement in proportions 1:2 by weight.

Solution. — For the mold used, it was estimated that 8 lbs. cement and 16 lbs. dry sand would be required. Gaging these with 3 lbs. 12.6 oz. (3.79 lbs.) of water, the quantity necessary for the desired consistency, the volume of the mortar was found by measurement to be 348 cu. in. when green, and 336 cu. in. after setting and pouring off the surplus water. The absolute volumes are expressed below, first in cubic inches and finally in terms of the density $(c + s)$ of the set mortar.

$$\text{Cement} = \frac{8 \times 1,728}{3.1 \times 62.3} = 71.6 \text{ cu. in.}$$

$$\text{Sand} = \frac{16 \times 1,728}{2.65 \times 62.3} = 167.4 \text{ cu. in.}$$

$$\text{Water} = \frac{3.79 \times 1,728}{62.3} = 105.1 \text{ cu. in.}$$

Absolute volume cement, sand and water,	344	cu. in.
Measured volume green mortar,	348	cu. in.
Volume of entrained air,	4	cu. in.
Percentage of entrained air,	1.2%	

$$\text{Density of set mortar, } c + s = \frac{71.6}{336} + \frac{167.4}{336} = 0.213 + 0.498 = 0.711$$

Feret's Formula for Strength. — For studying the relation of absolute volumes to strength, let

P = compressive strength of the mortar.

K = a constant which differs for different cements and at different ages of the same mortar.

c = absolute volume of cement.

s = absolute volume of sand.

w = absolute volume of water voids.

v = absolute volume of air voids.

The value of determining the density of mortars is made evident by the following law of Mr. Feret: *

"For any series of plastic mortars made with the same cement and inert sands, the compressive strength after the same length of set, under identical conditions, is solely a function of the ratio $\frac{c}{w+v}$ or $\frac{c}{1-(c+s)}$, whatever be the nature and size of the sand and the proportions of the elements — cement, inert sand and water — of which each is composed."

It follows from this law, as Mr. Feret says, that the strength of any mortar increases with the absolute volume of the cement (c) in a unit volume of fresh mortar, and also with the density ($c + s$), whatever may be the relative volumes filled with water and air.

From very numerous experiments, such as those in Table I., Mr. Feret, starting with the supposition that P is proportional to $\frac{c}{w+v}$, evolves the approximate formula

$$P = K\left(\frac{c}{1-s}\right)^2 \qquad (1)$$

By suitably changing the value of K, the formula may be adapted to either the English or the metric system of measurement.

As a proof of this formula Mr. Feret plots on a diagram, shown in Fig. 1, values of $\left(\frac{c}{1-s}\right)^2$ for abscissas, and the average compressive strengths for ordinates. Since in formula 1 K is equal to P divided by the square of the quantity in brackets, the value of K is the tangent of the straight line passing through the points. In Fig. 1

* *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, 1897, Vol. II., p. 1604.

$K = 1,965$, if the strength is in kg. per sq. cm.;

or

$K = 28,000$, if the strength is in lbs. per sq. in.

This particular value is applicable only to the cement used by Mr. Feret in his experiments and to specimens at the age of five months, but the principles involved are of general application.

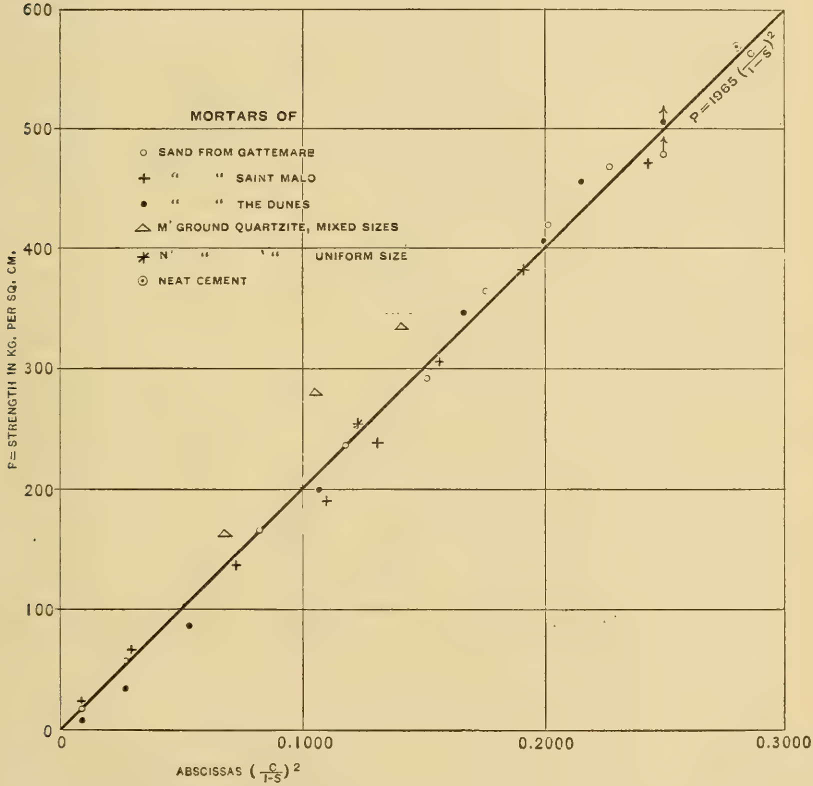

FIG. 1. DERIVATION OF FERET'S FORMULA FOR STRENGTH.
(*Bulletin de la Societe d'Encouragement pour l'Industrie Nationale*, 1897.)

The most practical application of this formula is in the determination of the relative compressive strengths of various mortars made from the same cement, with sand in differing proportions and of different compositions. Mr. Feret calls attention also to its possible use in laboratory experiments and specifications. A cement, for example, may be required to furnish, when mixed with any sand, a definite value of K, since the value of K is independent of the choice of the sand and of the composition of the mortar.

The speaker's experiments tend to show that the formula does not apply strictly to specimens of different consistency, but that the general law of the increase of strength with the density is applicable except in extreme cases. The formula is not exactly correct for tensile tests, although here, too, the general principle appears to hold good.

A graphical illustration of the relation of density to strength of mortars is shown in Figs. 3, 4 and 5. These diagrams are of the triangular form adopted by Mr. Feret, and the curves are reproduced from his drawings after transforming the values, where necessary, into English units. A study of the diagrams will suggest the practical value of the data which may be derived from them for comparing different mortars.

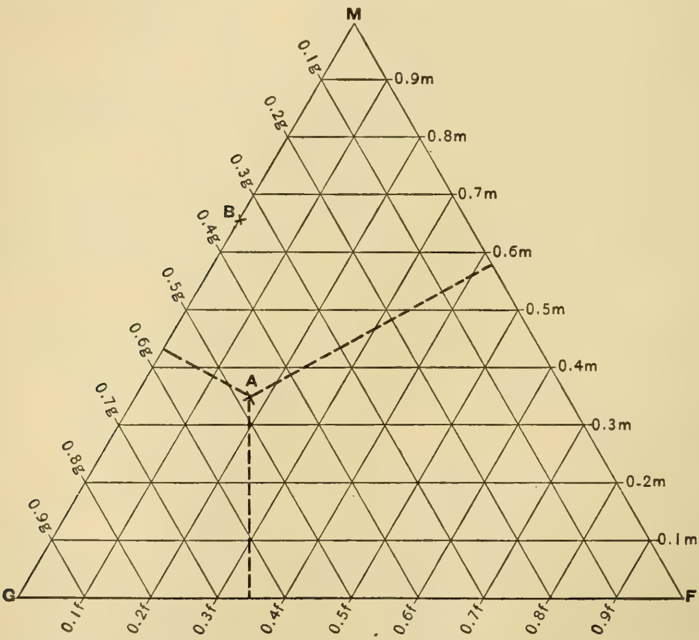

Fig. 2. Feret's Three-Screen Method of Analyzing Sand.

For those who are unfamiliar with such triangles, Fig. 2 is given to show their construction.

The sand is screened into three sizes, termed G (coarse), M (medium) and F (fine), and these sizes are mixed in various proportions. The proportions of a sand expressed as percentages, or rather as decimals of unity, are called its granulometric composition. The granulometric composition of any

sand is plotted as a single point in the triangle. The proportion of each of the three sizes in the sand is represented by its perpendicular distance from the side opposite each apex. For example, exactly at the apex G, the granulometric composition is g = 1.00, m = 0, f = 0. A sand represented by the point "A" in the triangle has for its granulometric composition, g = 0.48, m = 0.35, f = 0.17. Sand, B, whose point is on the line GM, is a mixture of G and M with no fine particles.

For comparing a special property of different sands, or of mortars composed of different sands, each sand employed in the tests is plotted and labeled with its value, — which may be in units of strength, weight or volume, — and "contour lines" are sketched in by the eye, as one would draw contours from elevations on a topographical drawing.

Any point on the same contour line represents a sand made up of the different sizes, G, M and F, in proportions corresponding to its perpendicular distances from the sides opposite each apex, but having the same strength, weight, volume, humidity, or whatever special function may be represented, as every other point on the same line.

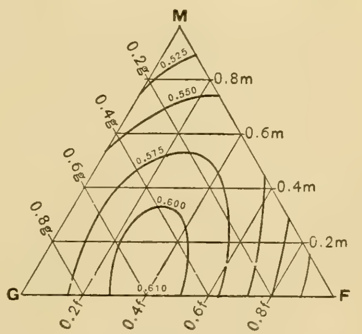

FIG. 3. ABSOLUTE VOLUMES OF SAND PER UNIT VOLUME OF SAND NOT SHAKEN.

Fig. 3 illustrates the use of the triangle for showing the volumes of sands composed of different sizes of grains. Any sand, for example, whose granulometric composition is represented by any point on the contour line labeled 0.575 in Fig. 3, has, when measured loose, 0.575 of its volume, or 57½ per cent. of absolutely solid matter, or, taking the complement, 42½ per cent. of voids. In Fig. 3 it will be seen that the greatest solid volume of loose sand is obtained by mixing G and F in proportions, 60 per cent. G and 40 per cent. F by weight. The amount of solid matter in this mixture of maximum density is 0.61 of the unit volume; in other words, the sand contains 39 per cent. voids. By interpolating between the contour lines we may see that a sand consisting of equal parts of the three sizes, which would be represented by a point at the geometrical center of the triangle, has about 0.597 solid matter, or 40.3 per cent. voids. In sands shaken to refusal the mixture of maximum density

consists of sands G and F alone, in proportions about 55 per cent. G, and 45 per cent F, and the total solid matter, that is, the absolute volume of sand, in a unit volume of the shaken sand of maximum density, is 0.798, corresponding to 20.2 per cent. voids.

Effect of Coarseness of Sand upon the Density and Strength of Mortar. — As a matter of fact, the actual size of a sand, that is, the size of its grains, is subordinate, in its influence upon the strength and other qualities of a mortar, to the density of the mortar produced from it. One naturally would suppose that the densest sand, that is, the sand which contains, when dry, the fewest voids, when mixed with a given proportion of cement, would make, inevitably, the densest and therefore the strongest mortar. Such, however, is not necessarily the case, for the addition of both the cement and water change the mechanical composition. A mixture of fine sand and cement, for example, requires a larger percentage of water in gaging than a mixture of coarse sand and the same cement. The total volume of a mortar of plastic consistency is affected by the quantity of water used, as well as by the volumes of the dry materials. Hence, a mortar consisting of fine sand and cement will be less dense than one of coarse sand and the same cement, even though the fine and coarse sands, when weighed or measured dry, each contain the same proportions of solid matter and voids.

Fine sand has more grains in a unit measure and therefore a greater number of points of contact of the grains. The water forms a film and separates the grains by surface tension. The voids in fine sand also are of smaller size than the voids in coarse sand, so that the grains of cement may be too large to enter them, and so force the grains of sand apart, thus further increasing the bulk of the mortar.

The effect of the water is graphically illustrated by comparison of the triangles in Figs. 3 and 4. In Fig. 4 the contour lines show the combined absolute volumes of the cement and sand in 1:3 mortar (proportioned by weight) made from sand of various compositions. It will be noticed that the point of maximum absolute volume, which is labeled 0.734, is much farther to the left than in Fig. 3, showing that for a mortar of maximum density, a sand is required containing more large particles, G, in proportion to the fine particles, F, than for maximum density with the same sand in its dry state. This is due to the fact that the fine sand takes more water and thus forms a larger bulk.

From such experiments Mr. Feret * derives the law that:

"The plastic mortars, which, per unit of volume, contain the greatest absolute volume of solid materials ($c + s$), are those in which there are no medium grains, and in which coarse grains are found in a proportion double to that of fine grains, cement included."

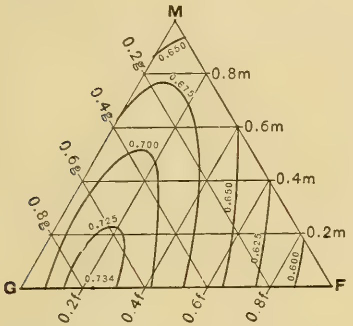

Fig. 4. Absolute Volumes of Solid Materials ($c + s$) per Unit Volume of Fresh Mortar in Proportions 1:3 (by Weight).

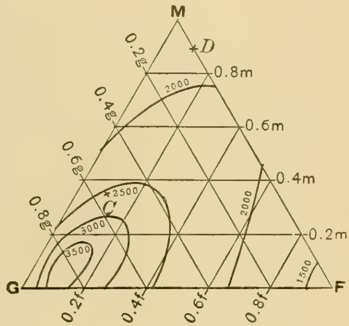

Fig. 5. Compressive Strength in Pounds per Square Inch of Mortars with Various Mixtures of Sand after One Year in Fresh Water. Proportions, 100 lbs. Portland Cement to 3.2 cu. ft. Mixed Sand.

Fig. 5 shows the strength in compression of mortars made from various mixtures of the three sizes of sand. It is of interest to note that the curves of strength in Fig. 5 occupy the same general position as the curves of density in Figs. 3 and 4. The point of maximum strength in Fig. 5 is farther to the left than the points of maximum density in the other figures because the decrease in density produces a decrease in the percentage of cement to the cubic yard of mortar, and therefore the strength is even more affected by an excess of fine material than is the density.

Practical Applications of the Laws of Density. — It is probable that some of you may question the practical use of all this. Sand from the same bank usually varies largely in different places, and even when sands of a uniform character are to be obtained, it is considered impracticable to mix two or more sizes on account of the expense involved. In other cases, only one quality of sand is obtainable, and consequently there is no opportunity for choice.

* *Annales des Ponts et Chaussées*, 1896, II., p. 182.

In answer to such criticisms, we outline below several conditions under which the investigation of the physical properties of the sand is not only interesting, but essential from the standpoint either of quality or of maximum economy.

(*a*) If two sands are available, a study of their physical characteristics will determine which is better suited to the work in hand as *the sand which produces the smallest volume of plastic mortar, when mixed with cement in the required proportions by dry weight, furnishes the strongest and least permeable mortar.*

(*b*) The variation of the sand in different portions of the same bank may be utilized by requiring the contractor to mix two sizes without exact measurement, so that the material as delivered shall contain not less than a certain percentage of sand coarse enough to be retained on a certain sieve.

(*c*) A good sand brought from a distance at a high price may be more economical than a poor sand from a neighboring bank.

(*d*) The relative value of crusher dust or of sand in a given locality may be determined by comparing their densities or the densities of mortars made from them.

(*e*) Frequently, a mixture of a fine and coarse sand, or of sand and crusher dust, proportioned according to their relative granulometric compositions or analyses, may be shown to produce a better mortar than either material alone.

(*f*) To produce impermeable mortar or concrete, it may be economical to screen a mixed gravelly sand into different sizes, and remix these in proportions which will produce a mortar of greater density.

(*g*) The value of "sand cements" for use in mortar and concrete under certain conditions may be made evident.

All these points may be determined without resorting to the expensive, tedious and sometimes misleading tensile tests of sand mortars, except as an auxiliary requirement or for checking the established conclusions.

The use of mixed sand, as described in (*b*), was adopted by Mr. Thomas F. Richardson, engineer, for the 1 : 2 natural cement mortar employed in the stone masonry of the Wachusett dam, after an exhaustive study of the comparative tensile strength and permeability of mortars made with different sands. He required the contractors to furnish sand so coarse that at least 50 per cent. would be retained on a sieve having 30 meshes per linear inch. The sand was excavated by scrapers, and the con-

dition was readily complied with, whenever the sand in one section was shown by samples to be running too fine, by taking alternate scraper loads of coarse sand from another place in the bank.

Numerous tests have been made in America * in proof of the general law that coarse sands are stronger than fine. Many experimenters have seemed to reach the result that coarse sand is stronger than mixed sand. In certain cases this is undoubtedly true, because of mixing the different sizes in wrong proportions, or because the mortar of coarse sand contains so large a proportion of cement that the voids are completely filled, and the addition of fine sand increases, instead of decreasing, the density. Mortar, for example, as rich as 1 : 2 (*i. e.*, one part cement to two parts sand) of coarse sand is as strong, and less permeable, than mortar of similar proportions made of almost any mixed sands; but with leaner mortars, a small admixture of from 20 per cent. to 25 per cent. of fine sand improves it. Natural sand which is in appearance very coarse almost invariably has a small percentage of very fine particles which, with the fine grains of cement, may assist, in the leaner mixture, in producing a dense mortar.

Sharpness of Sand. — In the past, all specifications have called for clean, " sharp " sand, in spite of the fact that in many parts of the country where sharp sand is not obtainable, sand with rounded grains is furnished and used with perfect satisfaction.

Comparative laboratory tests under conditions as nearly as possible identical uphold the practice of using sand with rounded grains. They indicate, as may be inferred from the previous discussion, that the chief difference in natural sands is due to the size of the grains, and while the sharpness of grain may exert a certain influence, it is of so much less importance than the size of the grain that the *requirement of sharpness for sand should be omitted from concrete specifications.*

Referring to columns 4 and 7 in Table I., and to Fig. 1, it is evident that the difference in strength of nearly all the mortars made with the various sands is explained by the differing percentages of cement and densities without reference to the character of the grains. The only noticeable exception is with the artificial sand, M, which consists of mixed sizes of crushed

* E. S. Wheeler in Report; Chief of Engineers, U. S. A., 1895, p. 3013; A. S. Cooper in Journal Franklin Institute, Vol. CXL., p. 326; Ira O. Baker in Journal Western Society of Engineers, Vol. I., p. 73.

quartz. Mr. Feret * believes that this exception may be due to chemical action produced by the large quantity (one-ninth its weight) of impalpable quartz.

Other tests of Mr. Feret † and comparative tests in the United States of mortar with crushed quartz and natural sands generally confirm the above conclusion.

Effect of Natural Impurities in the Sand upon the Strength of Mortar. — A clause to the effect that a sand for mortar or concrete shall be " clean " is almost universally found in masonry specifications. The necessity for this requirement is often questioned by cement experimenters, because the results of tests of mortar to which percentages of loam or clay have been added often give higher results than those of mortar made with cement and pure sand.

As a matter of fact, it is impossible to make a general statement either to the effect that loam or clay is beneficial or that it is detrimental to cement mortars. In some cases it is undoubtedly an actual benefit, while in others the contrary is true, chiefly depending upon the richness of the mortar and the coarseness of the sand. Lean mortars may be improved by small admixtures of loam or clay, or by substituting dirty for clean sand, because the fine material increases the density. Rich mortars, on the other hand, do not require the addition of fine material, and it may be positively detrimental, because the cement furnishes all the fine material required for maximum density. This is illustrated in experiments by Mr. Griesenauer ‡ in which an admixture of even 2 per cent. of loam (based on the weight of the sand) slightly reduced the strength of 1 : 2 mortar, while 20 per cent. of loam, added to the 2 parts of sand, reduced the strength about 30 per cent. In 1 : 3 mortar, on the other hand, the addition of 2 per cent. slightly increased the strength, and there was no appreciable injury up to 20 per cent. addition.

In experiments by Mr. E. S. Wheeler,§ clay reduced the strength of neat and 1 : 1 mortars, but improved leaner mixtures.

Strength of Plain Concrete. — Concrete is being used more and more extensively for structures where its strength and a

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* *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, 1897, Vol. II.

† *Annales des Ponts et Chaussées*, 1892, II., p. 124.

‡ *Engineering News*, April 28, 1904, p. 413.

§ Report of Chief of Engineers, U. S. A., 1895, p. 3004, and 1896, p. 2827.

knowledge of its strength are of the utmost importance. The laws governing the strength of plain concrete, that is, the effect of varying the proportion of cement, and the differences due to the employment of different aggregates, have never yet been clearly formulated. It is known that a 1 : 2 : 4 mixture is in general stronger than a 1 : 3 : 6, and it is recognized that some 1 : 3 : 6 concretes are stronger than others, but the causes of the variation of strength of different mixtures are, to most of us, still far from evident. The speaker has devoted considerable study to the laws governing the relative strength of concrete, and the results may be of interest as throwing some light on the subject.

At the outset it must, of course, be borne in mind that the experimental strength of concrete is not always a criterion for fixing the proportions of mixture; in fact, most concrete must be made stronger than the theoretical loading would require. A lean concrete, for example, although it may gain sufficient strength before the load is applied, may not be sufficiently strong at a short period to permit the removal of the molds or the ordinary wear during building, or, for many purposes, the lean concrete may be too porous.

It is known that the strength of plain concrete, that is, of concrete without steel reinforcement, is governed primarily by

(1) The quality of the cement.

(2) The texture of the aggregate.

(3) The quantity of cement in a unit volume of concrete.

(4) The density of the concrete.

The percentage of cement and the density of the concrete which are of special importance to the user in determining the proportions of materials, may be expressed more explicitly as follows:

(1) With the same aggregate, the strongest concrete is that containing the largest percentage of cement in a given volume of concrete, the strength varying nearly in proportion to this percentage.

(2) With the same percentage of cement, but different arrangement of the aggregates, the strongest concrete is usually that in which the aggregate is proportioned so as to give a concrete of the greatest density, that is, with the smallest percentage of voids. In many cases relative densities nearly correspond to relative weights.

Although these laws have been long recognized in a general way, having been partially proved by experiments of Mr. John

Grant as early as 1871, but few attempts have been made to apply them practically in the comparison of strengths of different mixtures of concrete.

Comparative Strength of Concrete of Different Proportions. — The formula for strength of mortar derived by Mr. Feret, as he himself states,* is not applicable to concrete. Our formula for concrete mixtures is therefore presented as a practical working formula of sufficient accuracy to compare the compressive strength of mixtures of the same materials in different proportions. Starting with the principles just laid down, it is evolved by trial to fit the average results of a large number of tests made in this country and Europe.

Let

P = unit compressive strength of concrete.

c = absolute volume of cement in a unit volume of concrete.

s = absolute volume of sand in a unit volume of concrete.

g = absolute volume of stone in a unit volume of concrete.

M = a coefficient, constant for all proportions of the same material mixed and stored under similar conditions, but varying with the texture of the coarse aggregate and the age of the specimen.

Then

$$P = M\left(\frac{c}{1+c-(s+g)} - 0.1\right) \qquad (1)$$

The absolute volumes, as indicated on a previous page, are really ratios of the actual volume of the concrete, representing the actual mass or total volume of solid particles in a unit volume of concrete. Since ratios are independent of the unit selected, the absolute units are the same for any system of measurement, and by changing the value of M, the formula is adapted to English or metric system. For example, if P expressed in terms of kilograms per square centimeter requires a value of $M = 880$, P in pounds per square inch will require a value of $M = 880 \times 14.2$ † $= 12{,}500$. It follows that knowing for a given age the value of M and the strength of a concrete composed of known percentages of materials, it is possible to estimate the compressive strength at the same age of any other concrete of exactly known composition made under like conditions from similar materials, but differently proportioned.

A very slight variation in the values of the terms will so

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* *Chimie Appliquée*, p. 522.

† Ratio for converting kg. per sq. cm. to lb. per sq. in.

largely influence the result that the formula is only useful, on the one hand, where the specific gravities of the materials and the weights entering into a unit volume of concrete are determined so accurately that the absolute volumes can be calculated, and, on the other hand, for comparison of the strength of different mixtures of concrete under assumed average conditions. For the latter purpose the specific gravity of cement may be taken at 3.1 and of sand at 2.65, the weight of a barrel of cement as 376 pounds, the weight of the dry sand contained in a cubic foot of moist sand as 89 pounds,* and the percentage of voids in the stone as 46 per cent. In computations, values of absolute volumes must be carried to three places of decimals.

Now let

P' = compressive strength in pounds per square inch.
c_b = barrels of cement contained in acubic yard of the concrete.
s_c = cubic feet of sand contained in a cubic yard of concrete.
g_c = cubic feet of stone contained in a cubic yard of concrete.
M' = a coefficient adapted to pounds per square inch.

Then from formula (1)

$$P' = M'\left\{\frac{c_b\frac{376}{193}}{1 + \frac{376}{193}c_b - 27\left(\frac{89}{165}s_c + 0.54\,g_c\right)} - 0.1\right\}$$

$$P' = M'\left\{\frac{c_b}{0.513 + c_b - 7.48\,(s_c + g_c)} - 0.1\right\} \qquad (2)$$

This formula, as stated above, is only adapted for average comparative determinations, or where the conditions exactly correspond to those assumed. It may be adapted to other sand and stone by altering the coefficients of s_c and g_c. Table II. is based upon these formulas, (1) and (2), with coefficient of g_c changed to correspond to the voids in the stone.

Formula (1) is based upon the actual strength of concrete, as determined by tests of Mr. E. Candlot in France and those of several other authorities at the Watertown Arsenal, U. S. A. To illustrate its agreement with actual experiments, tests of Mr. Candlot upon broken stone and gravel concrete 28 days old are plotted on the diagram, Fig. 6, and Mr. George A. Kimball's tests made at the Watertown Arsenal on specimens six months old in Fig. 7.

* With 3 per cent. natural moisture this is equivalent to 92 pounds per cubic foot, a fair average weight for natural bank sand throughout the United States.

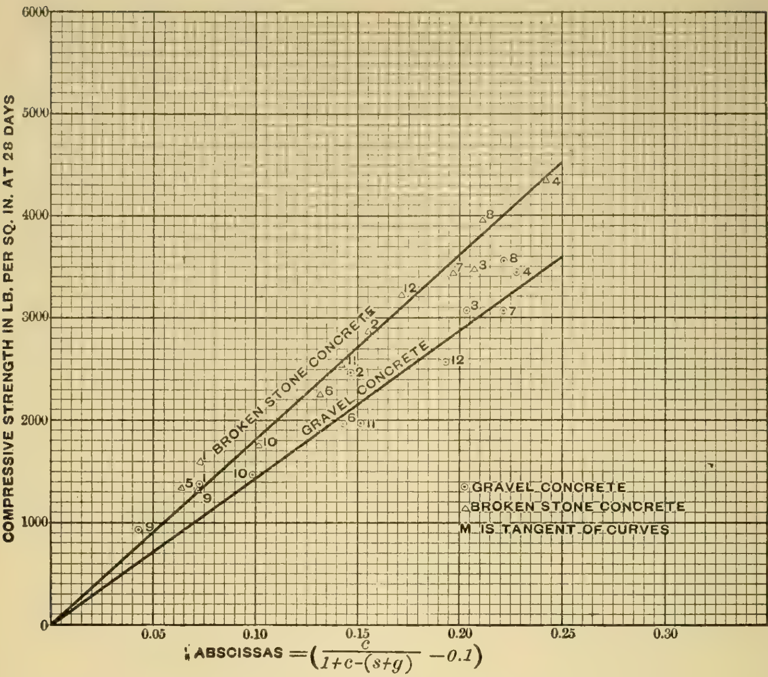

FIG. 6. COMPARISON OF FORMULA WITH TESTS OF E. CANDLOT.

The accuracy of the formula is shown by the nearness of the points on each diagram to straight lines starting from the origin. The abscissa of each point is determined by calculation of the term in brackets in formula (1), and the ordinate is the actual breaking strength of the specimen at the given period. The value of *M* in each case is the tangent of the straight line drawn through the points. If Mr. Candlot's tests are plotted on cross-section paper and smooth curves of growth in strength drawn through them, it will be found that the new values taken from such curves, which partially eliminate inequalities in the breaking, approach even more nearly to the straight lines.

After a study of the strength of concrete at different periods, the speaker would suggest the following values for *M* at different ages. The values for broken stone concrete are based upon stone ranging in size from 2 to 2½ inches down to ¼ to ½ inch. For broken stone of finer size the values will be slightly lower. The composition of the concrete does not affect the value of *M*, since the term of the formula in large brackets is itself dependent upon the proportions of the mixture and the density of the

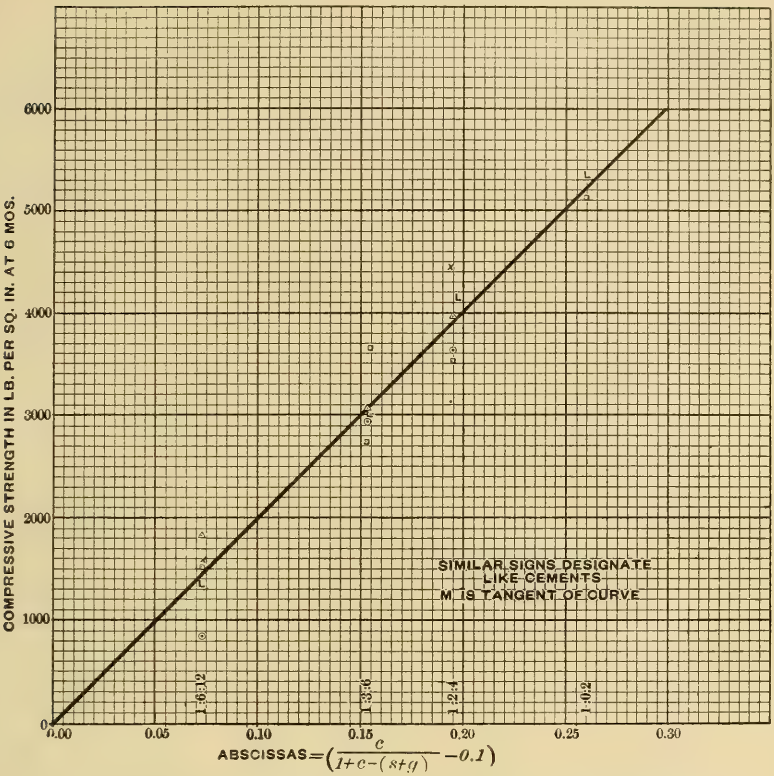

FIG. 7. COMPARISON OF FORMULA WITH TESTS OF GEORGE A. KIMBALL.

concrete. The values of M are directly proportional to relative strengths at different ages.

VALUE OF COEFFICIENT M FOR COMPRESSIVE STRENGTH IN POUNDS PER SQUARE INCH.

Age.	Coefficient M for Broken Stone Concrete.	Ratio of Growth Based on Age at One Month.
7 days	9,500	0.76
1 month	12,500	1.00
3 months	15,600	1.25
6 months	16,900	1.35
1 year	18,000	1.44

Table of Compressive Strength. — The strength of concrete mixed in various proportions, given in Table II, is based upon a strength with proportions 1 : 3 : 6, that is, one barrel cement to 11.4 cubic feet sand to 22.8 cubic feet stone, of 1,950 lbs. per square inch at the age of one month; this value being selected as the average of tests by different experimenters. It corre-

sponds to a value of M of 12,500. Using 1,950 lbs. per square inch for 1 : 3 : 6 as the starting point, the strengths for other mixtures are calculated from formula (1), the absolute units for the different proportions being deduced from the average quantities of cement, sand and stone contained in a unit volume of concrete. The assumption, which corresponds to average conditions, is made that a cubic foot of moist bank sand contains 89 lbs. of dry grains having a specific gravity of 2.65, and that the specific gravity of the cement is 3.1. The cement is assumed to be first-class American Portland and the stone equal in quality to sound, hard limestone.

TABLE II.

AVERAGE STRENGTH OF CONCRETE IN COMPRESSION.

Proportions.	Age One Month.		Age Six Months.	
	45% Voids in Stone or Gravel.	30% Voids in Stone or Gravel.	45% Voids in Stone or Gravel.	30% Voids in Stone or Gravel
	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.
1 : 1 : 3	2,630	2,550	3,560	3,440
1 : 2 : 4	2,440	2,350	3,300	3,170
1 : 2½ : 5	2,180	2,070	2,940	2,790
1 : 3 : 6	1,950	1,840	2,630	2,480
1 : 4 : 8	1,570	1,460	2,120	1,970

The values in the table may be readily transformed to safe working strength by dividing by the proper factor of safety. If concrete of special kinds of material mixed in certain proportions gives a higher or lower strength than that presented in the table, mixtures of these same special materials in other proportions may be assumed with approximate correctness to produce relatively higher or lower strengths than the tabular figures.

A point in the table which will appear inexplicable to users of concrete who have not carefully studied the true causes of strength in concrete is the fact that with the same proportions of mixture, the stronger concrete results with the stone having the larger percentage of voids. In explanation of this, it must be remembered that a material with a small percentage of voids contains in a unit volume, measured loose, a larger quantity of actual solids than a material with a larger percentage of voids. For example, stone with 30 per cent. voids has 70 per cent. of its bulk solid material, while one with 45 per cent.

voids has 55 per cent. of its bulk solid material. Now, each particle of solid material occupies space in the volume of concrete, and a given volume of loose stone with 30 per cent. voids will therefore make more concrete if the voids are filled with mortar than the same loose volume of 45 per cent. stone mixed with the same volume of mortar. In the case of 1 : 3 : 6 concrete containing stone having 45 per cent. voids, one barrel of cement will make 24.4 cubic feet of concrete, while with the same proportions and stone having 30 per cent. voids, one barrel of cement will produce 28.1 cubic feet of concrete. Conversely, there will be less cement in a unit volume of concrete with the stone having 30 per cent. voids. The density, on the other hand, will be but slightly increased, because, the same quantity of sand and cement being used, the particles of the stone containing the smaller percentage of voids are forced apart by the surplus mortar. The increase in density, in other words, is not sufficient to counterbalance the decrease in percentage of cement. If the proportions had been altered and the same percentage of cement, but less sand, used with the stone having 30 per cent. voids, the density of the concrete would have been greater than with the stone having 45 per cent. voids, and the per cent. of cement remaining the same, the concrete containing the stone with 30 per cent. voids would have been stronger than the other.

From this it must not be inferred that the aggregate with the largest percentage of voids is best to use. As indicated above, it requires more cement to a given volume of concrete, and the concrete is apt to be slightly less dense than with an aggregate having fewer voids, so that the latter is usually the more economical, even although it is sometimes slightly inferior in strength. In the example in the preceding paragraph, with Portland cement at $2.00 per barrel, the concrete with stone having 45 per cent. voids would require 0.15 bbl. cement more per cubic yard than the concrete with stone having 30 per cent. voids, and would therefore cost 30 cents higher per cubic yard.

Tests of Compressive Strength of Concrete. — A series of experiments upon 12-inch cubes made by Mr. George A. Kimball,* and tested at the Watertown Arsenal, covers so wide a range in time and proportions that more complete values are worth quoting and are presented in the curves in Fig. 8. Mr. Kimball's remarks with reference to the leanest mixtures are of

* Tests of Metals, U. S. A., 1899, p. 717.

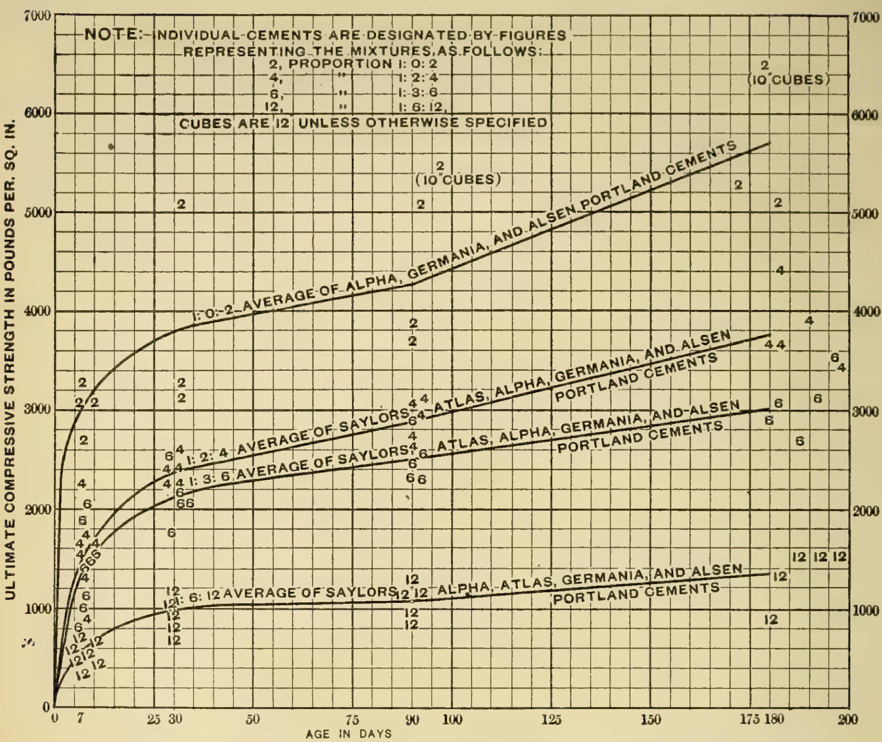

FIG. 8. TESTS ON CONCRETE CUBES BY GEO. A. KIMBALL (WATERTOWN ARSENAL, 1899).

interest as illustrating the frequent necessity of using richer proportions than the actual loading requires.

> "The 1:6:12 blocks were in poor condition. This was due to the difficulty of getting so lean a mixture well rammed into the corners of molds so small as 12-inch, and to the fact that the concrete had not attained sufficient strength, even though handled with care, to hold together well in the process of removal from the molds. The cubes of this mixture should have had a longer time to set before taking them out of the forms. In our foundation work we have used this mixture only as a filling with which to replace soft ground and on which to build the foundations proper."

The diagram in Fig. 8 shows Mr. Kimball's resultant curves* for the different proportions based on an assumed weight of cement of 100 lbs. per one cubic foot at the various ages. The results from individual brands of cements are shown by separate points.

* From data presented to the speaker by Mr. Kimball.

Variation in Weight of Concrete of Different Proportions. — The weights of specimens of similar concrete are of interest in comparing the relative strength of different mixtures or of different specimens of the same mixture. Of twelve pairs of duplicate cubes which the speaker had tested in 1903 at the Watertown Arsenal and the Massachusetts Institute of Technology, the heavier specimen, except in one case, was found to be the stronger.

The Effect of Concentrated Loading. — In concrete foundations for piers and in concrete footings, it is customary to load an area smaller than that of the surface of the concrete. The question at once arises whether the stress shall be based upon the load divided by the total area of the concrete footing or by the area of contact. Experiments made upon concrete and other materials show that neither of these methods is correct, but that an intermediate area should be selected for computation.

In conection with the designing of concrete footings for the Boston Elevated Railway, 12-inch cubes were crushed by concentrating the load upon plates 10 by 10 inches and 8 by 8½ inches.*

Curves by Mr. Kimball show the relative strength of concrete under concentrated loads to that under distributed loading, and illustrate on the one hand the increased strength under concentrated loading if figured on the compressed area, and on the other hand the decreased strength if figured on the total area. These curves are similar in general direction, and also in the actual values of the ordinates, to curves drawn by Prof. J. B. Johnson † illustrating Bauschinger's tests upon other materials than concrete.

Concrete vs. Brick Columns. — The compressive strength of brick piers is of interest to the concrete engineer for comparing brick and concrete columns. Tests made at the Watertown Arsenal and quoted by the Committee of the American Society of Civil Engineers on the Compressive Strength of Cement,‡ give the ultimate strength of common brick piers about eighteen months old as ranging from 800 to 2,400 pounds per square inch, the results for brick laid with lime mortar

* Tests of Metals, U. S. A., 1899, p. 740.

† Johnson's Materials of Construction, 1903, p. 33.

‡ Transactions American Society of Civil Engineers, Vol. XV., p. 717, and Vol. XVIII., p. 264.

averaging nearer the lower figure, and those for 1 : 2 Portland cement mortar nearer the higher figure.

Prof. William H. Burr,* after discussing the strength of brick piers under various conditions, states that

> "The results of all the experimental investigations available in connection with brick masonry and experiences in the best class of engineering work indicate that masonry laid up of good hard-burnt common brick may safely carry a working load of 15 to 20 tons per square foot, or 210 to 280 pounds per square inch. In the construction of this class of masonry where the duties are to be severe, it is of the utmost importance that the best class of Portland cement mortar be employed, as the carrying capacity of brick masonry depends largely, if not chiefly, upon the character of the mortar."

These values nearly correspond to usual requirements for columns of 1 : $2\frac{1}{2}$: 5 concrete.

The Strength of Concrete. — Using experimental crushing tests as a basis, the safe working loads may be assumed to range from $\frac{1}{3}$ to $\frac{1}{10}$ of the breaking loads, depending upon the various conditions which are outlined below. Although these limits appear extreme, corresponding, for example, for 1 : $2\frac{1}{2}$: 5 concrete at the age of one month, to 730 to 220 pounds per square inch, different conditions will often warrant as great a variation in the selection of the unit pressure.

In many structures the actual strength of the concrete does not enter into the calculation. The dimensions of a concrete foundation, for example, are often determined by the area of the superimposed structure, or else, on the other hand, by the bearing power of the soil. In such cases it often would be theoretically possible to come nearer to the working strength of the concrete by using very lean proportions, were it not prohibited by the porosity of the mass or its low strength at short periods. However, by grading the materials so as to reduce the voids, a lean mixture is often economical.

The unit pressure to be selected depends not only upon the strength of the concrete as determined by its proportions, the character of the raw materials, and the methods of mixing, but also upon the character and importance of the structure, the nature of the pressure, — whether by direct compression or bending, whether from a live or dead load, or whether acting

* Burr's Materials of Engineering, 1903, p. 428.

directly or through a cushion of inert material, — and the time of setting before placing the load.

The following arbitrary values are given as fairly representing modern practice.

Safe Compressive Strength of Concrete.

Character of Pressure.	Safe Strength at 1 Month of 1 : 2½ : 5 Mixture.* Lbs. per sq. in.	Tons per sq. ft.
Direct compression on mass concrete	400	29
Compressive stress in reinforced beams	625	45
Columns over 2 square feet in sectional area	350	25
Columns under 2 square feet in sectional area	300	22
Bearing of iron on concrete, such as bridge seats	400	29
Cinder concrete in direct compression	150	11

Piers or mass concrete subjected to pounding or vibrating load may require factors of safety nearly double the figures given and thus much lower working values.

Growth in Strength of Concrete. — Records from various tests made upon similar specimens of concrete at different periods are plotted in the diagram, Fig. 9. The curve illustrates the growth in strength which may be expected in ordinary average concrete made with first-class materials. The ordinates on the diagram represent ratios of the strength at various periods to the strength at the age of one month, in order that the curve may be of general application to various mixtures. If, for example, the strength of any concrete at one month is found to be 2,000 lbs. per square inch, the strength of the same concrete at the age of six months may be assumed to be 2,000 multiplied by 1.35, the ordinate at six months, or 2,700 lbs. per square inch.

The curve does not allow for the fact that the growth in strength varies to a certain extent with different materials, with different proportions, and with different percentages of water employed in mixing. With age, the strength of gravel concrete appears to gain on the strength of broken stone concrete. The growth, too, at periods beyond, say, three months, is undoubtedly affected by the hardness or strength of the particles of the coarse aggregate, since a concrete of poor material will reach its ultimate strength earlier than one of good material.

* Proportions based on a barrel of 3.8 cubic feet, average strength of this mixture being assumed as about 3,000 lbs. per square inch at the age of six months.

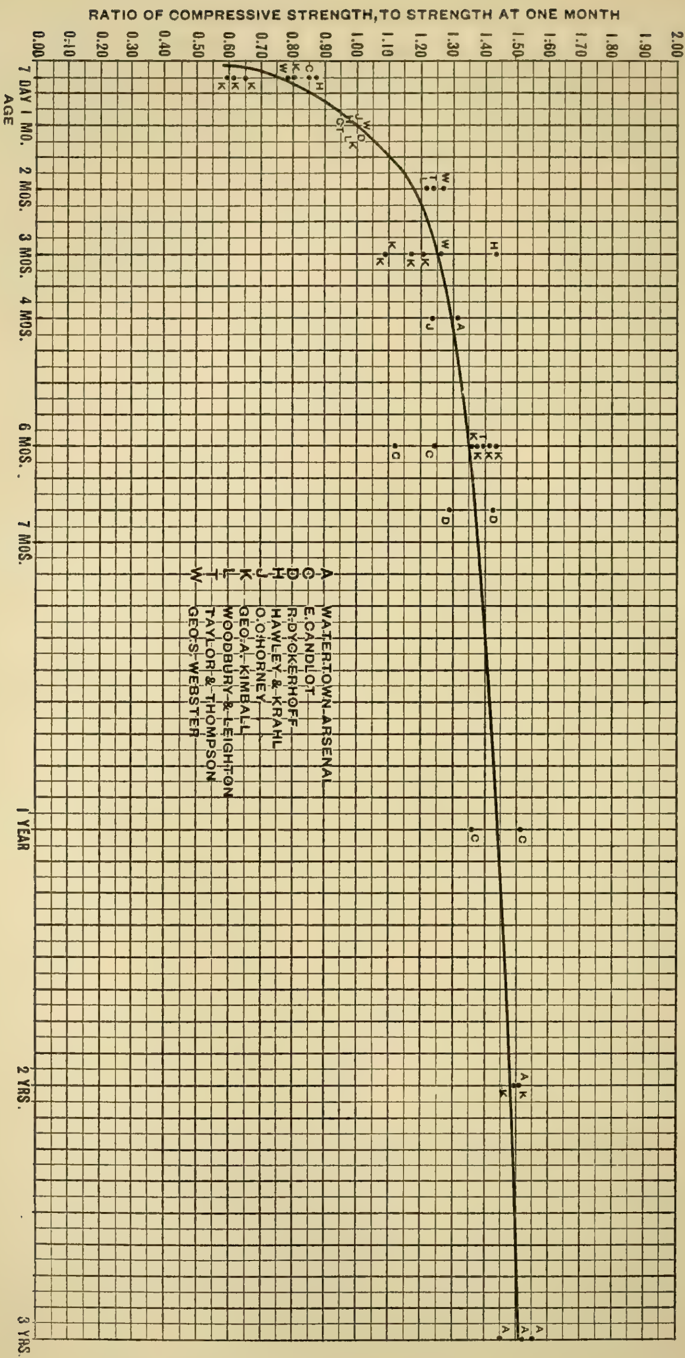

FIG. 9. GROWTH IN COMPRESSIVE STRENGTH OF PORTLAND CEMENT.

Transverse Strength of Concrete. — The best set of tests which have been made upon beams up to the present time are those by Mr. William B. Fuller at Little Falls, N. J. Fig. 10 gives the results of this series of tests of 6 by 6 by 72-inch beams. Although different materials than those used by Mr. Fuller will, of course, show slightly different strength, the values are sufficiently representative of average conditions to permit their use for comparisons of different proportions, and with a proper factor of safety, as a working guide to the safe transverse strength of concrete.

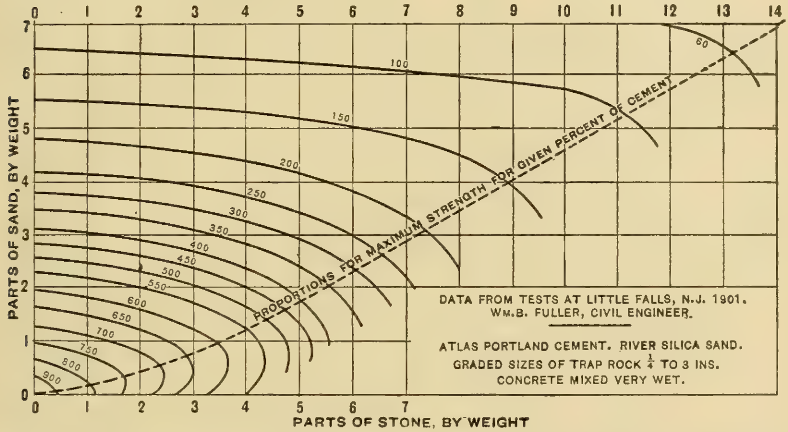

Fig. 10. Curves Showing Strength of Beams in Pounds per Square Inch for Various Proportions, by Weight, of Sand and Stone to One Part Portland Cement.

Effect of Varying Relative Proportions of Sand and Stone. — A few values selected from Mr. Fuller's tests referred to in the preceding paragraph illustrate the effect upon the strength of concrete of substituting more stone for a portion of the sand. The total amount of aggregate in each case is the same, namely, 1 part cement to 6 parts sand and stone, but the strength varies with the relative proportions of each, from 93 lbs. to 504 lbs.

Relation of Strength of Concrete to Relative Proportions of Sand and Stone.

Proportions by Weight of Cement to Total Aggregate.	Proportions by Weight of Cement to Sand and Broken Stone.	Modulus of Rupture, lbs. per sq. in.
1:6	1:1:5	504
1:6	1:2:4	439
1:6	1:3:3	355
1:6	1:4:2	210
1:6	1:6:0	93

Modulus of Elasticity of Concrete. — The modulus of elasticity, that is, the stress or load at any point in the test divided by the total strain or deformation of the specimen at the same point is an important factor in the design of reinforced concrete. The value of the modulus increases with the age of the specimen and with the richness of the mixture. From experiments by Prof. C. Bach of Stuttgart, Germany, in 1895, summarized by Mr. David Molitor,* it appears that the modulus of elasticity bears a definite relation, although not a fixed ratio, to the ultimate strength.

Different experimenters have reached exceedingly varied results in testing concrete for its modulus of elasticity. The differences, even in concrete composed of the same proportions of cement and aggregate, are often as great as from 1,500,000 to 5,000,000. The variation is due in part to the "personal equation" and the extreme delicacy required in measuring the deformation, and in part to differences in the quality of materials and in the methods of making and testing the specimens. Tests at the Watertown Arsenal given in the annual volume of "Tests of Metals," present excellent records for 12-inch cubes, but as the gaged length for measuring the deformation of 12-inch cubes can be no more than 5 inches, and since the true measure of elasticity cannot be determined upon specimens of this shape, these results may not be accepted as conclusive unless confirmed by tests upon long prisms. Experiments by Prof. W. Kendrick Hatt † give values ranging from 3,500,000 to 4,000,000 for 1 : 2 : 4 mixture, and the results of Prof. W. H. Henby ‡ upon specimens $2\frac{7}{8}$ by $3\frac{1}{2}$ inches by 11 inches long, give similarly high values.

The speaker also has found a modulus of about 4,000,000 in 12-inch concrete cubes mixed 1 : $2\frac{1}{3}$: $4\frac{2}{3}$, the crushing strengths of which were about 5,000 pounds per square inch at the end of two months.

Recent tests upon long columns, the results of which have not yet been published, indicate that lower values approximately equivalent to those obtained in Mr. Kimball's tests, hold for concrete of a character employed for reinforced construction.

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* Journal Association of Engineering Societies, May, 1898, p. 348.

† Journal American Society for Testing Materials, 1902, and *Engineering News*, February 27, 1902.

‡ Journal Association of Engineering Societies, September, 1902, p. 145.

Effect of the Consistency upon the Strength. — The general result of experiments and practice tends to show that the strongest concrete can be secured with a mixture containing only sufficient water to produce a film of mortar upon the surface after very hard ramming in thin layers, but with a wetter "quaking" mixture the ultimate strength will be nearly as high as with the dry mixture, and because of the greater ease in laying and obtaining a homogeneous mass, it is generally to be preferred. An excess of water injures the cement by decomposing parts of it before it has had opportunity to set. The actual strength of concrete is often of less importance than other considerations. If, as in many classes of structures, there is an excess of strength, cheapness in placing, the appearance of the surface, or the proper imbedding of reinforcing metal may be of primary importance. In such cases the quantity of water must be suited to the attendant conditions.

Tests by Mr. Taylor and the speaker indicate that (1) the consistency which will produce the densest concrete will result in the greatest ultimate strength, provided an excess of water is not employed; (2) dry mixtures attain higher strength at short periods, but mixtures of quaking consistency approach the dryer specimens after longer setting; (3) very wet mixtures, especially of lean proportions, may be chemically injured, but only to a slight extent, by the excess of water.

Effect of "Laitance." — Whenever concrete is laid under water, the water is likely to be clouded by what appear to be particles of cement floating up from the mass which is being laid. This whitish substance is generally termed "laitance." A similar formation occurs on the surface of concrete laid with a large excess of water. In certain cases, we have found as much as one-eighth inch rising from a layer of 1 : 2½ : 5 concrete less than five inches thick.

Chemical and microscopical analyses made by Mr. Clifford Richardson show that this laitance has nearly the same chemical composition, except for a large loss on ignition, as normal Portland cements, but consists largely of amorphous material of an isotropic nature, — that is to say, it does not affect polarized light, and has almost no setting properties. Mr. Richardson states that he has obtained a similar decomposed and hydrated material by shaking a sample of Portland cement in water, then decanting the finer portion and allowing this to settle and harden. In practice, the finer particles of the cement are suspended in the water and decompose before having opportunity to set.

It is evident, therefore, that when concrete or mortar is laid under water, or with a large excess of water, a portion of the cement is rendered incapable of setting, and the strength of the mass is consequently reduced in proportion to this loss. The conclusion is naturally reached that for concrete laid under water, or in locations where a large excess of water is required in mixing, a higher percentage of cement than usual, about one-sixth more, should be employed.

A lean mixture has been found to be more seriously injured by an excess of water than a rich one, probably because the water has a greater opportunity to penetrate the mass, and therefore to dissolve the cement.

Gravel vs. Broken Stone Concrete. — Comparative tests of broken stone and gravel concretes, in the same proportions by volume, show almost invariably that concrete made from hard broken stone, such as trap, or hard limestone, gives higher compressive strength than concrete made from gravel. This appears to be the rule not only when the materials are mixed by measured volumes, regardless of the percentages of voids, but also when the broken stone and gravel are each screened to substantially the same sizes.

The relative values of gravel and broken stone concrete in the following table are based on the comprehensive series of comparative tests made by Mr. Candlot in France.

Each ratio gives the extra strength of broken stone over gravel concrete of similar age. For example, if a concrete containing gravel having 40 per cent. voids tests 2,000 lbs. per square inch at the age of six months, a concrete in similar proportions by volume containing broken stone with 47.4 per cent. voids should, according to Candlot's experiments, test 1.20 times greater, or 2,400 lbs. per square inch.

Comparative Strength of Broken Stone and Gravel Concrete.
From Candlot's Experiments.

Age.	Ratio of Strength of Broken Stone Concrete to Gravel Concrete. With equal voids.	Broken stone 47.4% voids. Gravel, 40% voids.
7 days	1.30	1.33
1 month	1.26	1.19
6 months	1.18	1.20
1 year	1.12	1.09

It is noticeable that the gravel concrete approaches the broken stone concrete as its age increases. Since in many cases the ultimate strength of concrete is determined by the strength of its coarse aggregate, it follows that at, say, the age of a few

months, a gravel concrete may reach or surpass the strength of a broken stone concrete having a coarse aggregate of soft stone of low strength.

Although the claim is frequently made that gravel concrete is stronger than broken stone concrete, the authors have failed to find substantial proof of this. On the other hand, various records, among them a number of tests at the Watertown Arsenal,* tend to show the probable accuracy of Candlot's tests.

Another argument in favor of broken stone concrete lies in the fact that gravel is often covered with a film of dirt, difficult to remove, which lowers the strength. In experiments for the Boston subway † by Mr. Howard A. Carson, chief engineer, concrete beams made with washed gravel were about one-third stronger than beams made with gravel coated with a thin film of dirt.

Although the weight of evidence apparently favors broken stone concrete, it by no means follows that broken stone always should be used to the exclusion of gravel. In many instances, the ultimate strength of the concrete is of minor importance because the proportions of the concrete are determined by other considerations. Often, where strength is the criterion, but gravel is cheaper than broken stone, an additional percentage of cement may be economical. Moreover, the ultimate strength of gravel concrete is undoubtedly greater than that of concrete made with a poor quality of broken stone. With fixed proportions, gravel is cheaper for the contractor than broken stone, because a given loose volume makes a larger quantity of concrete.

In mixtures of like proportions by volume, the gravel concrete will have less cement in a cubic yard of concrete than a broken stone concrete unless the stone is well graded. Under ordinary conditions, to attain concretes of nearly equal strength, with gravel and with broken stone, the sand should be proportioned in each according to the volume and dimensions of the voids in the stone,‡ and the quantity of cement per unit volume of compacted concrete should be the same in each. The gravel

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* Tests of Metals, U. S. A., 1898, pp. 649 to 654.

† Boston Transit Commission, 7th Annual Report, 1901, p. 39.

‡ This can be better accomplished by trial mixtures, thoroughly compacted, of the dry aggregate, or, still better, of small batches of concrete, than by water measurements of the voids. The proportions of the aggregates giving the smallest bulk of concrete to a given weight of the mixture of aggregates will be the best.

concrete thus will be apt to be the denser, and this will tend to overcome the slight difference in strength due to the varying character of the surfaces of the particles of the gravel and broken stone.

Sometimes it is advantageous to mix a small percentage of gravel with broken stone.

Effect of the Size of Stone or Gravel upon the Strength of Concrete. — The dimensions of the largest particles of stone and gravel which may be used in a concrete are even often limited by practical considerations of mixing and placing. For ordinary work, it is often specified that the stone shall pass through a 2-inch, or, more often, through a 2½-inch ring. For ordinary mass concrete of wet consistency the limit may be placed as high as 3 inches. In some cases, however, the stone must be small enough to pack readily around reinforcing metal, while in walls whose surface is to be picked or washed, a better appearance will result with stones under, say, one inch diameter, although the strength of concrete appears generally to increase with the size of the largest particles of stone in the mixture. This is illustrated in experiments by Mr. Howard * at the Watertown Arsenal upon 12-inch cubes of 1 : 1 : 3 concrete made with uniform stone of different sizes. The weight of the specimens indicate that the increase of strength is due primarily to the density.

John Kyle † nearly doubled the strength of 1 : 2 : 6 concrete made with 1½-inch stone by substituting 4 parts of 3½-inch stone for a like portion of the 1½-inch.

Effect of the Quality of the Stone upon the Strength of the Concrete. — The ultimate strength of concrete is often limited by the texture or strength of the coarse aggregate. This is evidently the case with cinder concrete. Experiments by Mr. George W. Rafter ‡ gave the strength of concrete made with hard broken sandstone and various proportions of mortar from 1.5 to 2.4 times the strength of similar mixtures of broken shale and mortar, and this discovery led to the rejection of the latter as a material for concrete.

Tests of the speaker upon 12-inch cubes broken at the Watertown Arsenal lead him to believe that at least in certain cases the ultimate strength of a concrete is actually fixed by

* Tests of Metals, U. S. A., 1898, p. 654.

† Proceedings, Institution of Civil Engineers, Vol. LXXXVII., p. 88.

‡ Second Report on the Genesee River Storage Project, New York, 1894.

the shearing strength of the particles of stone which make up the aggregate. Cubes in proportions 1 : 2⅛ : 4⅝, based on a cement barrel of 3.8 cubic feet, attained an ultimate strength of 5,000 to 5,500 lbs. per square inch. On account of differences in the methods of mixing and ramming, some of the specimens reached this limit at the age of two months, while others did not attain it for six months; but it was noticeable that at whatever period the ultimate strength was reached, the planes of fracture were smooth, breaking through each piece of stone, whereas before the ultimate strength was reached many of the stones pulled out from the concrete, leaving jagged instead of smooth surfaces on the pyramids remaining after the cubes were broken to destruction. The stone employed for these specimens was a hard, dense trap. If a weaker stone had been used, it is probable that the piece would have sheared at a much earlier period and the ultimate strength would have been lower.

If concrete is mixed in such proportions or by such methods that the ultimate strength is reached before the stones shear, the strength of the particles of stone is a much smaller factor in the result.

DISCUSSION.

Mr. J. R. Worcester. — I have very little that I can say in the line of the paper of the evening. I have enjoyed it very much, and I am sure it is very useful and will be more useful when it shall be published so that we can get at the tables and data for use in designing. What I have had to do with concrete has been more in the line of examining structures that are built than in making specifications and determining exactly upon the quality of materials to be used. In looking at concrete that has been constructed, concrete beams and concrete slabs, it is often the case that it is impossible to reconcile the actual strength developed with the theoretical strength. I have found this difficulty more particularly in slabs that are constructed with deep reinforcement, such as the Columbian system, where the reinforcing bar is almost as deep as the slab itself and the center of gravity is in about the same position as the center of the slab. The ordinary methods of computation seem to give a very much lower strength for such a slab than has been developed in practice. That brings up the question as to whether such construction should be ruled out, because the engineers are not bright enough to know how to calculate it. The matter has come before me a number of times from the building commissioner of Boston, where, as yet, we have no

law governing steel concrete, and contractors have often been permitted to build floors on one system or another provided they will stand suitable tests. When such floors have been constructed and the building commissioner wants to test them, the question arises as to how much more the floor ought to be made to carry, where tested, in order to be sure of the portions that are not tested. I wish, if others have had experience on this point, they would give us the benefit of stating what they have used as the proper factor. My practice has been to rule that in buildings with the floors already constructed, if a few of the bays on test carry, without any sign of a crack, loads 3 times the working loads, the whole ought to be considered safe. In saying a load 3 times the working load, I mean three times the total load including the weight of the slab. If the live load is 50 lbs. per sq. ft., and the dead load 75, it makes a great deal of difference whether or not the dead load is taken into consideration.

As bearing upon the discrepancies between calculated and theoretical strengths, it might be interesting for the Society to hear of one or two tests that I have seen in Boston within the last year. Unfortunately, most of them were not carried to destruction; it would be a great deal more satisfactory if they were, but that is not often practicable in the case of buildings already constructed. If a floor is proved strong enough for its working load, the contractor does not want to destroy it for the sake of science.

One test was at the Norman Street School, on a stone concrete slab, having a span of about 11 ft.; the bay was 27 ft. 6 in. wide, and the whole bay was loaded. The slab was supported on steel beams riveted at the ends into the frame of the building. That is an extremely important feature, whether the slab tested is rigidly supported in this manner, or whether it is tested by itself simply resting on supports. In this case the slab was 6 in. thick, reinforced with Clinton wire mesh; the mesh was 4 in. by 4 in., and the wires 0.15 in. in diameter; the concrete was in the proportion of one, three and six; Alpha cement, sand and crushed stone; 11 days old when tested; the load was in the form of bags of cement piled along the center of the bay; the extreme width of the load was about 4 ft., but in computations it was assumed to be distributed over 3 ft.; but that was not an important assumption, the span was so long. In all, 370 bags of cement were used, or about 35,000 lbs. The first crack was observed on the lower surface with a load equivalent to 192 lbs. per sq. ft. uniformly distributed, or

262 lbs., including the dead weight. Beyond this point there was a marked increase in the rate of deflection. In this case, using Professor Hatt's method of computation and assuming the modulus of elasticity of concrete to be 4,000,000, as has often been done, the compression of the concrete at the time the cracks were observed was 2,650 lbs. per sq. in.; tension in wire, 196,000 lbs. per sq. in. Of course this is absurd. The explanation is that the concrete must have arched between the supporting beams.

Another test was made in another bay of the same building under the same conditions and it showed almost the same results.

This was a case where the question was asked what sort of reinforcement should be used. In the tests the load at the time of cracking was not quite 3 times the total load specified, and so the work was not approved in that form, and it was necessary to increase the reinforcement to some extent. If the slab were figured by modern methods, I think probably 6 or 8 times as much steel as was used would be required. The bays of the building were the same size throughout, so there appeared to be no reason why the result of the tests should not govern the construction. Considering that each of these nearly reached the desired strength, it was settled finally to double the reinforcement.

Another bay in that same schoolhouse was tested later, but not intentionally. In this case a bay very similar to the one first described, but with twice the reinforcement, was built in extremely cold weather and frozen when first laid. A week later the forms were removed from under it, and the contractor took occasion to pile all the broken stone to be used in that floor upon that bay. With the forms removed and the concrete frozen, on Sunday, about ten days after the concrete was put in, there came a heavy warm rain, and that night or early Monday morning the slab went down, and through the floors below it to the ground. As nearly as could be determined from the statements of the men, there was a load of about 400 lbs. per sq. ft. on the concrete. The concrete was less than two weeks old at the time. It was so frozen that the next day in looking at the fragments they were glistening with the frost. As soon as it thawed out it was almost as soft as when put in.

Another interesting test was witnessed at the Harvard Medical School on Longwood Avenue. There a 10 ft. 2 in. span, 4 in. thick, of stone concrete, laid between beams riveted

to a header at one end and built into a wall at the other, was reinforced in two different ways and tested with a uniformly distributed load over each portion. The reinforcement in one part consisted of Clinton welded wire mesh, the wires about 9-64 in. in diameter, spaced 3 in. apart. In another part the reinforcement was ½ in. twisted square rods, 7½ in. apart on centers. The concrete was 1, 3 and 5; Penn-Allyn cement, sand and stone, 1 in. and ½ in. mixed; age, 27 days. The load was in the form of brick piled on edge, the long dimension being parallel to the beam, the bricks being laid so as not to bear on each other. The bricks were applied one layer at a time until the load reached a total of about 445 lbs. per sq. ft., including the dead load. At that time the test was stopped, as it was over the required three times the working load. The increase in deflection on this 10 ft. span between a load of 200 and 445 was 3-16 of an inch. This slab was 20 feet wide, one-half reinforced with mesh and half with twisted rods. Both portions acted the same, so far as deflection was concerned. No cracks could be discovered. Using the Hatt method of computation we find the unit stress on the Clinton mesh was 250,000 lbs. per sq. in.; the compression on the concrete about 4,500 lbs. per sq. in.; and in the other half, reinforced with the twisted rods, there was a compression in the concrete of 2,170 lbs. per sq. in.; tension in steel 22,500. It is evident the slab must have arched between the beams, in one half, at any rate.

Another bay at the Harvard Medical School was tested later. That had one-half reinforced with Clinton wire mesh and the other half with rods, ⅝ in. square, 12 in. on centers. Lehigh cement was used. The only difference from the first test in the results noticeable was that with a load of 277 lbs. per sq. ft. there was a slight crack in the half reinforced with Clinton mesh, and on this part the load was not carried any farther. On the other half the load went to 445 without any sign of a crack and with only very slight deflection.

I have also notes of two tests made at the Boston Storage Warehouse on St. Stephen Street. The first was a test of a reinforced concrete beam of T section. The beam was one of a series spaced 6 ft. 2⅝ in. on centers and having a span of about 14 ft., 8½ clear, the ends butting into 20-in. I-beams and really resting on the haunches built up from the bottom flange. The I-beams were 15 ft. 7½ in. on centers. The slab between the concrete beams was 4 in. thick, reinforced with expanded metal near the bottom of the slab at the center, and raised almost the depth

of the slab over the concrete beams. The reinforcing of the beam consisted of four $\frac{7}{8}$-in. round rods near the bottom through the central portion. Two of these rods extended the whole length of the beam, and were bent at right angles near the web of a steel girder where they terminated. The other two were bent upwards at an angle of 45° near the quarter points of the span, whence they were carried horizontally over the tops of the steel girders, and anchored into the top of the concrete beam in the adjoining bays. Vertical stirrups were used near the ends of 7-16-in. round iron. The size of the beam was $8\frac{1}{2}$ in. wide by 15 in. deep below the bottom of the slab, and the slab was connected to the beam by a small fillet. The concrete was made 1 : 3 : 5, except in the lower portion of each beam, where the proximity of the rods made it impossible to get in stones, and there the proportions were 1 : 1 : $2\frac{1}{2}$, the stone being in the form of crusher dust. The cement was Lehigh, of good quality, except as to fineness, which showed a residue from 24 to 27 per cent. on 200-mesh sieve. The stone was Roxbury pudding stone, three-fourths of it about 1 in. in diameter, and two-fifths about $\frac{1}{2}$ in. The sand was clean, coarse and sharp. A wet mixture was used throughout, the mixing being done by the Smith mixing machine, and not being as uniform as might be desired; age, 40 days. The load was applied in the form of pig iron, which was laid in piles kept separate from each other, the pigs being laid with the beams. These were placed over a width of 6 ft. $2\frac{3}{4}$ in., the center of the load over the center of the beam. Careful observations of the deflection showed it to be almost exactly proportional to the loads. The total amount reached was 7-128 in., with a total load of 668 lbs. per sq. ft.

In calculating the bending moment there is a good deal of uncertainty as to how much assistance was given by the continuity of the beams over the steel girders and the slabs extending to other concrete beams. Assuming that the load was all carried by the beam in question, and that the center moment was Wl^2 divided by 10, and that the effective depth of the beam was 15 in., the strain in the rods amounted to 45,000 lbs. per sq. in. The exact strain in the concrete is not easily determinable.

Another test was made in the same building under similar conditions to the first one, except that the beams were stronger, being 9 in. in width by 45 in. deep, and the slab was $4\frac{1}{2}$ in. deep instead of 4 in. In this case the load amounted to 737 lbs. per sq. ft. live load, or 812 lbs. total, causing a deflection of a

scant 1-16 in. In each case the load was left on for a number of days without any change.

Making the same assumption as in the case of No. 1, the strain in the steel amounted to 41,400 lbs. per sq. in.

Another test that I have noted is in cinder concrete. In this case it was in a schoolhouse at City Point, the floors of which were constructed by the Roebling Construction Company. I had the privilege of seeing the test, and it was extremely interesting. The results were high. A slab with a span of 10 ft in the clear, 5 in. thick, was reinforced with 2-in. by $\frac{3}{16}$-in. bars placed vertically, 12 in. on centers. The concrete was 1, $2\frac{1}{2}$ and 6, Lehigh cement, sand and steam ashes, except a thin surfacing, which was made of 1, 2 and 4 screenings; age, 38 days. The load was applied in the form of sand in a wooden box. In this case it was a test slab not enclosed by a frame. The load was carried to a total of 340 lbs. per sq. ft., with an extreme deflection of three-eighths of an inch, which, after carrying the load for three days, recovered within 3-64 in. Applying the methods of computation that I have before employed to the test, and assuming a modulus of elasticity of cinder concrete of 750,000, the fiber strain in concrete was 980 lbs. per sq. in., while the strain in the steel was 41,400 lbs. per sq. in. Nine hundred and eighty seems very high for cinder concrete. Mr. Thompson recommends 150. This is 6 or 7 times as much without any sign of failure.

Another cinder concrete test I saw was a slab constructed by the Eastern Expanded Metal Company for the Bussey Institute. In this case a slab 3 ft. wide, 8 ft. between supports, reinforced with 3-in. No. 10 gage expanded metal, was tested to destruction. Two sheets of reinforcing metal were used, overlapping each other 4 ft. at the center. This arrangement of reinforcing made the weak spot under a uniform load at the end of the double sheet of metal, and it was at this point that the first fracture occurred. The ends of the metal sheets were turned up towards the top of the slab. The supports were not connected together outside of the slab. The concrete in this case was 1 : $2\frac{1}{2}$: 5, and was 33 days old. The load was applied in the form of brick, arranged so as not to arch. As the load increased, the rate of deflection gradually increased also, being 1-64 in. for each tier of brick at the start, and 1-16 in. for each tier near the end. Failure occurred when the load reached 325 lbs. per sq. ft., and the deflection was about $\frac{3}{4}$-in. As before stated, the first crack occurred at the

end of one of the sheets of expanded metal 2 ft. from the center, and ran horizontally along the metal and upwards toward the center. According to my calculations at the time of failure there was a compression in the concrete of 880 lbs. per sq. in., and a strain on the steel of 62,000 lbs. per sq. in. It was evident that the failure started from the steel being overstrained.

Another test which I will speak of was interesting only from the effect of frost on cinder concrete. The roof of the Beacon Hill building was laid about the 1st of January in extremely cold weather. It was said by the workmen that the night following the laying of most of the concrete, the thermometer went to zero and stayed there for a week. At any rate, when I first saw the concrete, which was in March, it was so soft you could kick into it with the heel of your boot. It was just beginning to set. If you took a light hammer you could easily dig right through it. The concrete was poorly applied; it was reinforced with expanded metal which showed through on the bottom in a considerable part of the roof; it was not buried in the concrete. It seemed that it could not make a good job, and together with one or two others, I was misled into recommending to have it torn out. The contractor insisted that it should have more time, and it was allowed. In the interval, the contractor plastered the under side with cement, and a week or two of warm weather dried the upper surface. The setting which had been so long delayed took place as it naturally would if it had never been frozen, and by April 6, when tests were made, it was in such condition that in each of the four bays tested, a load equivalent to 244 lbs. per sq. ft. was supported with a deflection on a 5 ft. 6 in. span of not over $\frac{1}{8}$ in.

Mr. H. A. Carson. — I would like to ask Mr. Thompson whether he made any observations upon the shrinkage of concrete, that is, for example, the length of a beam, not due to changes of temperature, but to crystallization of the concrete itself.

Mr. Thompson. — I have never made any experiments of that kind. I think I spoke of wet concrete shrinking. This merely referred to the setting of the heavy materials and forcing the excess water to the surface.

Mr. R. A. Hale. — I should like to ask Mr. Worcester if his slabs were flat straight across, or arched in any way.

Mr. Worcester. — In every case they were straight slabs, not arched.

Prof. C. M. Spofford. — I wish to point out the large

shearing values given in Table I. I remember that, at the time this Society had under consideration the proper units to recommend for insertion in the proposed revision of the Boston Building Laws, we selected 30 lbs. per sq. in. for the allowable shearing value of concrete. The breaking values in the table vary from 1,000 to 2,000 and 3,000 lbs. per sq. in. Do you know how these values were obtained?

MR. THOMPSON. — I do not think they were very scientifically obtained, not so much so as most of Mr. Feret's work. The form of specimen was an overhanging beam, 2 cm. (0.8 in.) square by 6½ cm. (2.6 in.) long, firmly held between two supports, one below and one above, and loaded as close as possible to the supports so as to avoid bending it, as shown in Fig. 11. Later, Mr. Feret made some tests which are mentioned in his book, "Chimie Appliquée," in which he made a cube of neat cement with a layer of the mortar to be tested running through it in a diagonal plane, so that it would shear on this mortar plane.

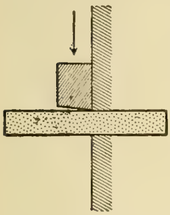

FIG. 11.
SHEARING TEST.

PROF. SPOFFORD. — The results from these were very similar, were they not?

MR. THOMPSON. — Yes.

PROF. SPOFFORD. — We made a few tests at the Institute this year upon the shearing value of concrete. The specimens were cylinders 5 in. in diameter, and 15½ in. long, with their ends supported in cast-iron blocks which fitted the cylinders exactly. The load was applied to the cylinders over the central span of 5 in. through a semi-cylindrical cast-iron block which fitted the concrete cylinders so exactly, and was such a tight fit between the supports, that there was very little chance for bending. Our values were high as compared with the breaking load which would correspond to a working load of 30 lbs. per sq. in., although they were not as high as those given in Table I. Unfortunately, I have been unable to look up all the data of these tests in time for this meeting but I will read a brief summary of the results. In order to prevent misunderstanding it should be noted that all the values which are given were computed on the assumption that the cylinders sheared simultaneously on two sections, and that the shearing stress was distributed uniformly over the cross section of the cylinder.

Mixture.	No. of Tests.	Time of Set. Days.	Average Time of Set. Days.	Average Shearing Strength. Lbs. per sq. in.
Neat cement.........	5	35 to 63	53	2,753
1 : 2 mortar	5	27 to 32	29½	1,318
1 : 3 ,, ...	5	26 to 29	28	839
1 : 2 : 4 concrete......	8	25 to 30	27	1,082
1 : 3 : 5..............	10	21 to 26	23½	560
1 : 3 : 6..............	9	25 to 29	27	612

I hope at a later date to bring these tests more fully before the Society, but I think that so far as they go they would tend to show that a working unit of 30 lbs. per sq. in. is, to say the least, a very conservative value.

MR. THOMPSON. — A paper on "Strength of Concrete" is incomplete without more definite reference to reinforced concrete beams. The speaker has referred to the variations in the position of the neutral axis under different conditions, and a comparison which he has made between theoretical calculations and the actual measured locations found in the experiments by Prof. Arthur N. Talbot at the University of Illinois may be of interest. These experiments as well as those of Professor Turneaure and Professor Marburg, were presented to the American Society for Testing Materials at the 1904 session.

The aim of such important series of tests of reinforced concrete beams is toward the establishment of laws and the confirmation of theories which will enable us to design beams of reinforced concrete with minimum quantities of steel and of cement and yet with positive assurance of safety.

The most important point which has been clearly, and it would seem positively, established by these tests, is the fact that the pull in the tension portion of the beam is actually transferred to the steel at an early period in the test, usually before the working strength of the beam is reached. This is indicated not only by Professor Turneaure's observation of the water-marks, but as well by the marked change in character of the curves in the various diagrams, when the load is transferred to the steel. The practice, which has already been generally adopted, of neglecting all strength of the concrete in pull, may therefore be considered correct, not only from the point of view of safety, but also from a rational standpoint.

Another conclusion — an extremely important one in the opinion of the speaker — that may be drawn from the tests, especially from those of Professor Talbot which embrace the

widest range in reinforcement, is that computations made according to the usual beam theories (based on the elasticity and the stresses in the concrete and the steel) produce values for the location of the neutral axis, and also for the ultimate moment of resistance, which are so near the experimental results that the theoretical formulas may be safely employed, if proper unit stresses and moduli are used.

The proof of the lack of tensile resistance in the concrete under normal loading enables us to consider the resistance of the beam as a couple, whose forces are the pressure in the concrete and the pull in the steel, and whose arm is the distance between these forces. Therefore, the moment of resistance may be obtained by taking moments about both forces, and adopting the lower value.

The location of the center of pull in the steel is evidently at the center of gravity of the steel rod or rods. The location of the center of pressure in the concrete has not yet been clearly fixed because the various experiments in this country and abroad have been made with concretes of various and, in many cases, undefined, proportions and consequently of different strength and elasticity. The location of the center of pressure of the concrete is based on the location of the neutral axis in the beam and the distribution of the pressure above the neutral axis, which, in turn, if the fundamental principles of theory are correct, depend upon the moduli of elasticity of the steel and the concrete.

In the table which follows are presented for comparison the actual location of the neutral axis as determined by Professor Talbot's experiments, column (7); the values calculated by his empirical formula, column (8); the values calculated by the theory of the straight line distribution of pressure, column (9), and by the theory of the parabola distribution of pressure, column (10); also Professor Talbot's estimated bending moment in column (11), and the moment of resistance calculated by the straight line and by the parabola theories in columns (12) and (13).

The measured depths of the neutral axis, column (7), are taken directly from Professor Talbot's tabulation of the actual positions during the third stage of each beam, as given in his paper in the *University of Illinois Bulletin*, September, 1904.

The close agreement of the values by Professor Talbot's formula, column (8), with the measured values, indicates the possibility of determining for such a formula, constants, each of

COMPARISON OF PROFESSOR TALBOT'S RESULTS WITH THEORETICAL COMPUTATIONS.

Beam No.	Kind of Steel.	No. of Rods.	Size of Rods.	Ratio of Area of Steel to Beam above Steel.	Load Considered.	Ratio of Depth of Steel to Depth of Neutral Axis.* As Measured.	Calculated by Talbot's Formula.	Calculated by Straight-line Theory.	Calculated by Parabolic Theory.	Estimated Total Bending Moment.*	Moment of Resistance Calculated from Straight-line Formula.	Moment of Resistance Calculated from Parabolic Formula.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
			in.		lb.					in.-lb.	in.-lb.	in.-lb.
21	Round	3	½	0.0041	8,000	0.34	0.33	0.33	0.29	261,000	226,890[b]	226,850[b]
19	Round	3	½	0.0041	9,200	0.36	0.33	0.33	0.29	294,600	226,890[b]	226,850[b]
16	Square	3	½	0.0052	9,900	0.37	0.35	0.36	0.32	313,200	284,700[b]	284,550[b]
17	Square	3	½	0.0052	9,500	0.37	0.35	0.36	0.32	302,000	284,700[b]	284,550[b]
27	Square	4	¾	0.0156	25,000	0.53	0.54	0.54	0.49	725,500	774,000[a]	793,200[b]
9	Ransome	3	½	0.0052	18,000	0.34	0.35	0.36	0.32	540,000	474,500[c]	474,200[c]
15	Thacher	3	¾	0.0083	15,500	0.41	0.41	0.43	0.39	466,000	443,300[b]	442,300[b]
10	Thacher	3	¾	0.0083	14,500	0.43	0.41	0.43	0.39	438,000	443,300[b]	442,300[b]
22	Kahn	3	¾	0.0167	22,000	0.57	0.56	0.55	0.50	641,000	786,200[a]	843,000[b]
4	Kahn	5	½	0.0139	21,000	0.47	0.51	0.52	0.47	615,000	714,800[b]	711,800[b]
14	Kahn	4	½	0.0111	17,000	0.46	0.46	0.48	0.43	505,500	580,400[b]	578,600[b]
5	Kahn	3	½	0.0083	13,000	0.42	0.41	0.43	0.39	396,000	443,200[b]	442,300[b]
28	Johnson	6	¾	0.0152	31,000	0.53	0.53	0.53	0.48	893,500	768,700[a]	927,800[a]
13	Johnson	7	½	0.0097	27,500	0.45	0.43	0.46	0.41	800,500	681,400[a]	817,700[a]
20	Johnson	5	½	0.0069	20,000	0.44	0.39	0.41	0.36	593,500	615,600[a]	621,200[b]
2	Johnson	5	½	0.0069	19,000	0.39	0.39	0.41	0.36	565,500	615,600[a]	621,200[b]
7	Johnson	3	½	0.0042	13,000	0.33	0.33	0.33	0.30	401,000	384,400[c]	384,200[c]
3	Johnson	3	½	0.0042	12,000	0.31	0.33	0.33	0.30	373,000	384,400[c]	384,200[c]
					Av'ge	0.418	0.411	0.422	0.378	506,906	507,388	533,711

NOTE. — Columns (1), (2), (3), (4), (6), (11) are taken from Professor Talbot's table. Just within the load points of the beams the area of steel in the Kahn bars was smaller than tabulated in column (5), and therefore the loads and moments of the Kahn beams cannot be directly compared with the other beams.

* As calculated by Professor Talbot, based on "Load Considered," column (6).

[a] Based on crushing strength of concrete 2,030 lbs. per sq. in., because the moment thus obtained is lower than the moment based on yield point of steel.

[b] Based on yield point of mild steel as 36,000 lbs. per sq. in.

[c] Based on yield point of high steel as 60,000 lbs. per sq. in.

which will apply to a certain class of concrete. The exact values of the constants are of course dependent upon the strength and elasticity of the concrete, and therefore the values given in the original formula cannot be applied directly to concrete of a different character.

The theoretical calculation for the location of the neutral axis is much simplified by the elimination of tensile resistance in the concrete, and if the general principles of most of the theories are correct, the location of the neutral axis after the pull has been transferred to the steel must lie either in the position calculated by the straight line distribution of pressure, — which assumes that a plane section before bending is also plane after bending and that the modulus of elasticity is constant during working

limits, — or by the parabola theory, — which assumes a clearly defined decrease in the modulus, — or else between these two positions. The values in columns (9) and (10) therefore present extremes with the modulus of elasticity selected.

In calculating columns (8), (9), (10) and (13) of the table, the modulus of elasticity of concrete is taken at 1,500,000. Professor Talbot's tests * of elasticity show this to be a fair average value for the concrete which he used, between pressures of 1,000 and 1,700 lbs. per sq. in., stresses which correspond to the pressure in the beam when the neutral axis is as measured. This modulus also gives, by the straight line theory, proportional values for the location of the neutral axis which are nearest to the measured locations. By the parabola theory a still lower modulus would have shown better results.

In calculating the values for the moments of resistance, the yield points of the steel are taken at average values for high and low steel respectively, so as to compare the tests with results which would be reached by theoretical calculations. Similarly, the ultimate crushing strength of the concrete is assumed as 2,030 lbs. per sq. in., which is the average strength found by Professor Talbot in his tests upon 6-in. cubes.

It is noticeable that the neutral axis calculated by the straight line theory of pressure distribution, column (9), agrees almost exactly with the measured values in column (7). The ratios by the parabola theory are lower, that is, the location of the neutral axis in the beam is higher. It is also interesting to observe that the values in columns (9) and (10) are nearly but not quite proportional to each other.

The moments of resistance in column (12) agree as nearly as could be expected with the estimated bending moments in column (11). The moments calculated by the two theories, columns (12) and (13), agree almost exactly in the tests based on the pull in the steel. In tests (28) and (13), in which both columns are based upon an ultimate strength of concrete of 2,030 lbs. per sq. in., the parabola values are nearer to the actual bending moments than the straight line values, showing that for the latter a crushing strength of concrete higher than 2,030 ought to have been assumed. On the other hand, tests (27), (22), (20) and (2), which by the parabola theory have to be calculated from pull in the steel, because this gives the lower moment of resistance, are not in column (12) quite so near to the estimated bending moments as by the straight

* Journal Western Society of Engineers, August, 1904.

line theory which assumes the concrete to be the limiting material.

As I have already said, the important part which the quality of the concrete plays in reinforced beams has sometimes been overlooked in theoretical studies of the combination of concrete and steel. This is well illustrated by the fact that Professor Talbot's beams, as stated above, require calculation with the use of a modulus of elasticity of not more than 1,500,000, corresponding to a ratio of 20, in order to bring the neutral axis as low in the beam as his measured depths. To obtain theoretical results with Professor Hatt's beams* agreeing with actual tests, one must employ, as Professor Hatt suggests, a modulus of about 4,000,000, corresponding to a ratio of 7.5. For Professor Turneaure's tests, I find a modulus of 2,500,000, or a ratio of 12, to give locations of the neutral axis which fairly agree with his experiments. The reason for such variation presents an important field for experimental investigation.

The formulas † used in calculating the location of the neutral axis columns (9) and (10), and the moments of resistance, columns (12) and (13), are as follows:

Let

p = ratio of area of steel to area of beam above the center of gravity of the steel.

C = unit pressure in outside fiber of concrete.

S = unit pull in steel.

$r = \frac{E_s}{E_c}$ = modulus of elasticity of steel divided by modulus of elasticity of concrete in compression.

d = distance from outside compressive surface to center of gravity of steel.

xd = distance from outside compressive surface to neutral axis in a beam having steel at depth, d, below the outside compressive surface.

x = ratio of depth of neutral axis to depth of steel, from outside compressive surface.

M_r = moment of resistance.

By the straight line theory, the proportional depth of the neutral axis is

$$x = rp\left(\sqrt{1 + \frac{2}{rp}} - 1\right) \qquad (1)$$

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* Proceedings American Society for Testing Materials, 1902.

† The derivation of these formulas is presented in Taylor and Thompson's treatise on "Concrete, Plain and Reinforced," 1905.

and the formula for the moment of resistance is

$$M_r = pSbd^2\left(1 - \frac{x}{3}\right) \qquad (2)$$

or

$$M_r = \frac{Cxbd^2}{2}\left(1 - \frac{x}{3}\right) \qquad (3)$$

Similarly, by the parabola theory, the proportional depth of the neutral axis is

$$x = \frac{3}{4} rp\left(\sqrt{\frac{8}{3rp} + 1} - 1\right) \qquad (4)$$

and the formula for the moment is

$$M_r = \frac{2}{3} Cxbd^2\left(1 - \frac{3x}{8}\right) \qquad (5)$$

or

$$M_r = Spbd^2\left(1 - \frac{3x}{8}\right) \qquad (6)$$

OBITUARY.

William Ellery Channing Cox.

MEMBER OF THE TOLEDO SOCIETY OF ENGINEERS.

MR. Cox was born in Philadelphia, Pa., June 12, 1837. In this city he was educated, and at the age of twenty-one commenced an active life in positions of trust and confidence as assistant superintendent of the Fairmont Rolling Mill Company. In this position, which he held until 1862, his ability and integrity were recognized by men of affairs to such an extent that his services were eagerly sought for places of authority in iron, railroad and mining enterprises; and he subsequently held, with honor to himself and credit to his associates, the positions of superintendent, general manager, trustee and vice-president of the several companies with which he was identified. In 1904 he moved to Toledo and became the representative of the Cambria Steel Company and Pennsylvania Railroad Coal. In the summer of 1904, his health began to fail, and during the fall he continued to grow weaker and was unable to give much attention to his business affairs. He was called from this life December 17, 1904, and is survived by a family of four sons and two daughters, his wife having died in 1901. Mr. Cox was one of the early members of the Toledo Society of Engineers and felt a deep interest in its success, but was prevented by his health from taking a very active part in its work. He was genial and affable, and made many warm friends in every circle in which he moved. His thorough knowledge of the steel and iron business, his position here as the representative of the Cambria Steel Company, brought him into contact with large interests and many business men, all of whom learned to admire him for his manly qualities, and respect him for his abilities.

Mr. Cox was a thorough Christian gentleman, and was actively connected with the Church of Our Father in this city. The Toledo Society of Engineers feel that they have lost a member who was an honor to them, and one who would have greatly advanced the prosperity of the Society had he been longer spared to them. To his bereaved family the members of the Toledo Society of Engineers hereby extend their heartfelt sympathy.

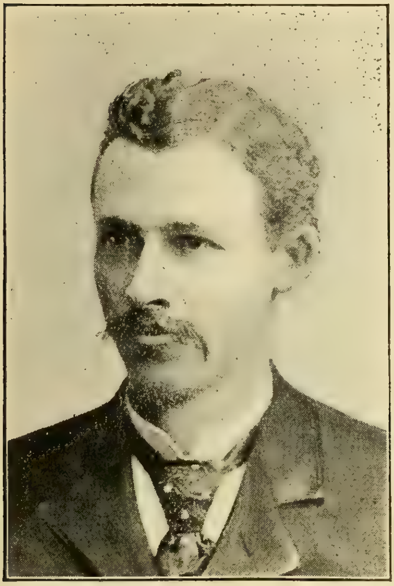
H. E. RIGGS.
F. T. OAKLEY.
C. S. DAVIS.

Burr Bassell.

MEMBER TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Born in West Virginia, September 25, 1858. Died in Los Angeles, February 25, 1905. Aged forty-seven.]

MR. BASSELL received his education in the University of West Virginia and in Washington and Jefferson College, Washington, Pa., which he attended for five years, graduating with the degree of A.B. in 1881. He took an additional course of three years' study in the Le Moyne School of Applied Mathematics, and, in 1883, attended law lectures at the University of Virginia. Having passed the examinations required, he was admitted to the bar in December, 1883, but never intended to practice law. In the spring of 1884, he removed to California, and began the practice of his chosen profession in Los Angeles, with the county surveyor and city engineer. The field of his subsequent labors continued to be on the Pacific coast, up to the time of his death. During the earlier years of his life here, Southern California had not entered upon that period of active development which subsequently attracted the attention of the world so strongly, and the career of a young engineer was one of struggle and discouragement. During all this period, however, Mr. Bassell maintained unfaltering courage and wore the same breezy, energetic, confident air of one who was sure of himself and his future, and determined to win recognition. He was not only cheerful himself, but inspired many other young men of his acquaintance to persevere, study and make the most of what were, oftentimes, pitifully meager opportunities for advancement. He was a constant student, and remarkably systematic in preserving, arranging and indexing the great mass of information which he was ever collecting to add to his library. His industry was tireless, and he was always equip-



ping himself for the greater achievements of the bright future he could see before him.

While his practice was quite general and covered a wide range, from land surveying to railway construction, sewerage and irrigation, he made a specialty of hydraulics, and was most interested in that branch of engineering. His most prominent work was the design and construction of the Tabeaud dam for the Standard Electric Company, near Jackson, Amador County. This dam is one of the highest and largest earth dams in the world, and has proven a most successful work in every respect. As a result of this experience, he wrote a textbook entitled "Earth Dams," published in 1904 by the Engineering News Publishing Company. In 1890–91, he was office engineer for the Arrowhead Reservoir Company, San Bernardino, Cal., designing and preparing drawings for canals, tunnels, trestles, flumes and earthwork diagrams. He was appointed United States deputy mineral surveyor for the district of California, in 1891. In 1892 to 1896, was assistant city engineer under J. H. Dockweiler, designing structures for the city irrigation and stormwater systems, superintending sewer construction of brick, concrete, vitrified clay, cast-iron and wood-stave pipe, paving and sidewalks, tests of cement, brick, asphalt and pile foundations. In 1899, Mr. Bassell was assistant engineer to a board of experts engaged in designing a new system of sewerage for the city of San Francisco. Subsequently he was engaged as locating engineer for the Gila Valley, Globe & Northern Railway. During the two or three years preceding his death, he was engaged as resident engineer in charge of construction of the plant of the Kern River Company for power development on Kern River, near the town of Kernville, a plant costing over $2,000,000 and successfully delivering power to Los Angeles, 130 miles distant.

A few weeks prior to his untimely end he had been selected by Mr. James D. Schuyler to the position of chief engineer of an important irrigation project in Texas, involving construction of a very large dam, and a reservoir covering some 10,000 acres, and was to have started the very week of his fatal illness. Mr. Bassell was a consistent Christian who was never ashamed to make profession of the faith, and manifested the same vigor and energy in the Baptist Church as characterized his professional work.

The malady with which he was stricken was pronounced spinal meningitis, and came upon him with such suddenness that he died the very day after his last work in the office. Funeral

services were held in Los Angeles, but the remains were taken to Clarksburg, W. Va. (where his mother and immediate relatives reside), accompanied by his stricken wife and daughter, Louise, a child of twelve years, but old enough, however, to appreciate the loss of the fond father, whose hopes had been so deeply centered upon her as his only child.

Mr. Bassell has set an example of industry, systematic order, neatness, intelligent inquiry, pursuit of knowledge, "up-to-date" and practical Christianity which could be followed to advantage by all who came within his sphere of influence.

JAS. D. SCHUYLER,
OTTO VON GELDERN,
Committee.

Charles Mason Wilkes.

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, April 19, 1905.]

HE was born May 29, 1858, in South Manchester, Conn., was reared there and attended its public schools.

In September, 1877, he entered the Massachusetts Institute of Technology; was the first president of his class, and was graduated in the architectural course in 1881. During the school year, 1881–82, he was assistant in applied mechanics. He was able, earnest and faithful in all that he did, both as student and as assistant. His interest centered on the constructive or engineering side of architecture rather than on that of design. In accordance with this tendency, he took up the work of assistant in applied mechanics at the time when the department had acquired its first testing machine, and begun the experimental investigation of the strength of materials by tests of full-size timber beams. In connection with this work, including the devising of suitable apparatus, he showed great energy and enthusiasm.

For most of the time from July, 1882, to November, 1885, he was an assistant engineer for the city of Boston for work on the Back Bay in connection with Stony Brook and Muddy River, and here also he showed energy and enthusiasm as well as intelligent appreciation of the work to be done.

From February to June, 1886, he was employed as assistant on tests at Watertown Arsenal, Watertown, Mass.

He went subsequently to St. Paul, Minn., where he was engaged in important public sanitary matters.

During the year 1891, he was the resident engineer for the contractor for the construction of a sewerage system for the business portion of Winona, Minn., and had sole charge of the work. In spite of the many difficulties connected with this piece of construction he carried it out to the credit and satisfaction of all concerned.

From Winona he was called, in the winter of 1891–92, to take the position of first assistant engineer in the division of Water Supply, Sewerage and Fire Protection of the World's Columbian Exposition. He occupied this place until the termination of the Fair, November 30, 1893, and upon him chiefly fell the arduous labors and grave responsibilities involved in the great undertakings in construction and development called for by his department, which he fulfilled with eminent success.

He then became the steam heating, sanitary and mechanical engineer of the firm of D. H. Burnham & Co., architects, and the exceptional ability with which he conducted his work contributed greatly to the success of his employers. His work included arranging for proper space in the buildings, preparing specifications, letting the contracts and supervising the installation of every piece of machinery used in the largest structures, including not only that for heating, lighting, plumbing and ventilating, but also the elevators, engines and boilers, dynamos and motors, circulating pumps and ice machinery. It is stated that in this connection he developed ideas which have been revolutionary in their effect upon the refrigerating industry.

In 1899 he developed schemes and prepared specifications for the steam heating and ventilating of the imperial palace, then in course of construction at Tokio, for the Crown Prince of Japan.

Mr. Wilkes was a member not only of the Boston Society of Civil Engineers, but of The American Society of Mechanical Engineers, The American Society of Heating and Ventilating Engineers, The Western Association of Engineering Societies and of the Northwestern Alumni of the Massachusetts Institute of Technology. He was an associate member of the American Institute of Electrical Engineers and belonged to the University, Kenwood and Mendelssohn clubs of Chicago.

January 27, 1897, he married, in Chicago, Miss Addie May Smith. He was a kind and loving husband and his married life was an exceptionally happy one.

Mr. Wilkes's untimely end is thought to be due to overwork. About five years ago it caused an acute attack of nephritis, and thereafter his health was a constant source of anxiety to himself and to his friends. He so far recovered from this attack, however, that he successfully met the increasing pressure of business and covered the broadening field of interests and responsibilities. December 9, 1904, accompanied by his wife, he went to Philadelphia to inspect the work of his department in the Wanamaker Building, hoping he might also obtain much needed rest. He had not been as well as usual for some time, but was supposed to be progressing satisfactorily under a physician's care. Without warning, however, came the sudden and fatal change. The coma of uremic poisoning ensued and without suffering he died peacefully and quietly January 7, 1905.

The burial was at Joliet, Ill., the former home of Mrs. Wilkes.

He possessed exceptional business capacity and had high ambition for his work. In letters, languages and music he was gifted and he had unusual ability as a pianist and organist. He was a sympathetic and witty conversationalist and a delightful companion. He had a markedly genial nature, was very considerate of others and was steadfast and loyal in his friendship.

H. A. Carson,
Gaetano Lanza,
Committee.

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RECENT TERMINAL IMPROVEMENTS IN ST. LOUIS.

By Daniel Breck.

[Read before the Engineers' Club of St. Louis, January 18, 1904.*]

In the production of the recent terminal improvements in St. Louis, those now constituting the engineering force were called on, both to define the problems which presented themselves and to provide the remedies. That is, the work of this force did not consist wholly in executing works whose necessity had been defined by others, but it became their duty, in part, to look over the situation as a whole, declare wherein terminal facilities, as they then existed, were inadequate to handle the business committed to them, and devise and execute improvements which should, if possible, supply these deficiencies. This paper will not be a technical description of certain engineering works, with detailed plans and formulæ of applied mathematics, but it is the intention to give a somewhat general view of the problems as they presented themselves to those whose duty it was to solve them, and of the methods employed in defining difficulties and reaching solutions.

The work accomplished, while, perhaps, presenting no very strikingly novel features of engineering design or construction, required some unusual applications of general practice, brief descriptions of which it is hoped will be of some interest.

The whole terminal situation in St. Louis is a very interesting one from a railroad transportation point of view, because

* Manuscript received March 6, 1905. — Secretary, Ass'n of Eng. Socs.

it represents the largest experiment now in progress, in the way of concentration of railroad transportation, both in freight and passenger lines. This claim can be sustained without fear of successful contradiction. This does not imply that there are more carloads of freight handled by the Terminal Railroad Association of St. Louis than by any other terminal, or that more passenger trains or passengers arrive at or depart from its Union Station than from any other passenger station, because it is probable that neither of these things is true. It is true, however, that at St. Louis more railroads have united with this Terminal Association in having all their terminal work transacted by one agent, than at any other point which can be named.

In a certain sense the question of whether such concentration could be successfully carried to the point which it has reached in St. Louis was on trial, and those intrusted with the problems in St. Louis realized that it was not unlikely that their success or failure in solving the problems in this case would be accepted, in many instances at least, as a demonstration that concentration could or could not be carried successfully to the point reached here. At the time the improvements were undertaken, it almost seemed that the demonstration was against such concentration, and that the great volume of traffic passing through the terminals had reached such proportions that it could not be successfully handled and distributed by one organization. Freight congestions on both sides of the Mississippi River were continuous, and a large proportion of every day's business was subjected to costly and exasperating delays. Freight cars in the course of systematic handling, familiar to all transportation men, would be sidetracked and left for days or even weeks in certain stagnant points alongside the great current of movement. The public suffered much inconvenience from these delays, and no citizen of St. Louis is unfamiliar with the meaning of the words "freight congestion." In the same way, there was a great deal of vexatious delay to passenger traffic, and trains would sometimes be detained for an hour or more almost within sight of the Union Station, while the passengers looked longingly at the "promised land." Even if the through passenger succeeded in reaching the station and making connection, he was often compelled to leave St. Louis unconscious of the fact that his baggage did not accompany him. If he were a traveling man, of course, when he reached his destination and learned that his baggage was not on the train with him, his natural diffidence prevented him from mak-

ing a great outcry about it, and threatening the Terminal Railroad Association of St. Louis with extermination unless the baggage were delivered to him instantly, whether it was on the train or not. Seriously, however, this condition of affairs caused much inconvenience and anxiety to persons who were familiar with conditions of travel through the St. Louis gateway.

It is hardly doubtful that, if a vote could have been taken at the time referred to, a decision would have been reached that it was impossible to handle such business as reached the St. Louis Union Station regularly without greater delay than would have been incurred if the station had been broken up into separate terminals scattered throughout the city.

The decision of this question rested largely with those who undertook to show that the St. Louis terminals could be so arranged as to handle the business at one station without abnormal delay. Other cities which found it necessary to undertake enlargement of their passenger facilities found themselves confronted with the question of whether it would be better to try to handle all the business of the city in one station or to subdivide it among several. Kansas City, for example, was debating this very question; Chicago was complacently answering it in favor of the Chicago system, by which the various roads enter four or five large terminals, widely separated and scattered throughout the city, making it necessary for their passengers to transfer from one terminal to the other by some other line of conveyance, either bus, carriage or street car.

Aside from the fact that the St. Louis terminals had very large amounts of money invested in the plant at that time, which fact, itself, was enough to make it necessary to continue to use one Union Station if it could possibly be accomplished, the arguments usually advanced in favor of separate terminals, excluding the question of the feasibility of doing it at all in one terminal, are based on an economic fallacy. The arguments that Chicago derives benefit from the transfer of through passengers by reason of the fact that they have to breakfast in the town, or have to contribute money which supports the transfer companies, or that the railroads must hire a large number of agents to transfer the baggage from one depot to the other, bring back to mind directly the almost forgotten Erie fight, so-called, of fifty years ago, which is very interestingly described in a recent publication by Mr. Frank Spearman, called the "Strategy of Great Railroads." Briefly stated, that war began in an effort of two of the short lines of railroad of that day to

consolidate, one entering Erie, Pa., with a 6-ft. gage and the other leaving Erie with a 4 ft. 10 in. gage, necessitating transfer of all freight and passengers at Erie. From Buffalo to Cleveland, in those days, two changes of cars were necessary, one at Dunkirk and one at Erie, and when it was decided to change the track gage of the roads meeting at Erie, so that passengers might ride from Buffalo to Cleveland, through Erie, without changing cars, a local war ensued that has never anywhere been paralleled in our country. The people of Erie used the same arguments that we hear used to-day, that Erie would be made a way station, its hotel business ruined and its busses put out of business. The transfer of passengers at Erie meant that passengers had to get meals there, live stock being transferred had to be fed, reloading of freight gave employment to a large force of freight handlers, etc. These arguments were so used to stir up the people that, as told in the volume referred to, on the morning of December 7, 1853, the people assembled at the ringing of the courthouse bell and tore down the long wooden railroad bridge over the river at Erie. During the course of three years' agitation that followed, this bridge was rebuilt and again torn down and burned for the same cause. While the Erie war offers an extreme case of futile resistance to progress, it illustrates the fallacy which lies at the bottom of all such opposition; and I think it will undoubtedly be demonstrated in the future that, at least, the great through lines of travel must not be broken by an intermediate journey on some form of local conveyance, with the attendant uncertainty of making connections with passengers, baggage and mail, and with the growing disposition of travelers to accomplish a long journey without even changing cars. Therefore it was believed that the best interests of this community would be served if the experiment of handling all travel at one Union Station could be made a success.

Those in charge of the terminals, therefore, found themselves, in the language of the street, "up against it." They found that business, both passenger and freight, was not being handled in a way to meet modern requirements, and they had to attack the problem in detail, find out why it was not being so handled, and what, if anything, could be done to handle it properly.

The first phase of the problem recognized was a lack of good internal circulation; that is, lines of free, uninterrupted movement throughout the property itself. This must include main lines open for free movement from all outlying parts of

FIG. 1. SYSTEM OF MAIN TRACKS AS REALIZED BY THE NEW CONSTRUCTION.

the property leading direct to the Union Station, as well as ample lines of movement connecting the various important points within the terminal territory, one with another. These main lines must not only be constructed, but they must be kept open for movement, and every device that was known to expedite movement must be adopted to increase the efficiency of these lines. Therefore, at the thirteen important and complicated crossings or junctions of these lines with themselves or with the lines of the various individual railroad companies, elaborate interlocking plants were established, requiring a total of 976 levers, and along the main lines wherever movement could be expedited in that way, the lines were equipped with automatic block signaling in such a way as to give continual notice to trains as soon as the lines were cleared for them to proceed. Fig. 1 gives an idea of the main lines of the terminal as realized by these improvements. Almost everywhere the movement called for at least double-track main lines. At many points, such as Granite City, Madison yard and along Hall Street, St. Louis, three and four tracks were provided, while at the point where the passenger train movement was most concentrated, namely, opposite the Union Station, seven lines of main track, one for freight and six for passenger movement, were provided. This, together with yard re-arrangements, required the building or rebuilding of over 138 miles of track.

The Eads and Merchants bridges were taken into consideration under the general heading of this main line movement. It was found that both these bridges required strengthening of many members in order to put them in condition to carry the heavy engines now in use. The Eads Bridge was strengthened so as to take an increased load of 20 per cent., and the Merchants Bridge an increased load of 30 per cent. Obviously all power must move freely over these bridges unless they were to present serious obstruction to proper movement, as the selection of light power and attaching it to trains before they could move over the bridges would cause confusion and delay. Furthermore, if a light engine can take only 25 carloads over the bridge and a heavy one could take 50, the number of movements would be doubled if light engines must be used exclusively, and thereby the number of movements, already too great, would soon have exceeded the capacity of the tracks.

The tunnel at the west end of the Eads Bridge offered still further obstruction to free movement. Two interlocking towers, one at the east end and one at the west end of the tunnel, although

placed as close to the end of the tunnel as they can properly be, are about 1.1 miles apart, and the time required by a train to clear the distance between them is approximately four minutes. In addition to other incidental disadvantages of operating in this tunnel, there is a sharp curve, nearly 12°, about midway in the tunnel, and the section of the tunnel is so small as to prevent the proper elevation of track to allow for a high-speed movement around this curve. Furthermore, for the most obvious reasons, the tunnel is operated under what is known as the absolute lock and block system, that is, one train cannot enter the tunnel until a train preceding it on the same track has gone entirely through the tunnel and come out at the other end. This protection is secured by a system of interlocked signals requiring the concurrence of the operators at both ends of the tunnel before train movement is allowed through the tunnel. As easily seen, the result of this is, that only fifteen trains can use the tunnel in each direction per hour, and as there were times both morning and evening when trains were leaving and arriving at the station at the rate of 89 trains in 60 minutes, those destined via the tunnel even came to a greater number than 15 per hour. The Merchants Bridge was, however, not being worked to its full capacity; so the main lines were made to include an opening up of routes in such a way that traffic which had been going over the Eads Bridge could be, if necessary, diverted over the Merchants Bridge. In this way, even high-speed passenger trains which formerly ran through the tunnel and over the Eads Bridge were made to take the comparatively circuitous but relatively high-speed line over the Merchants Bridge, with the result that, as in the case of the Vandalia and Baltimore & Ohio lines especially, the loss of time was only from three to five minutes over schedule, while the actual loss of time which might have amounted to an hour or more was saved.

If this were a technical paper, the whole of it might well be devoted to a description of the work on the Eads Bridge. This is in itself a very beautiful structure. It is a continual source of interest and pleasure to observe the intricate and everchanging geometrical figures which appear in fine tracery when the lines of this bridge are silhouetted against the sky. The work of strengthening it, which was done by Mr. J. C. Bland, engineer of bridges of the Pennsylvania lines west of Pittsburg, has been done in such a way as certainly not to mar in the slightest degree the beauty of the bridge. The scientific way in which strengthening members have been applied at the weak

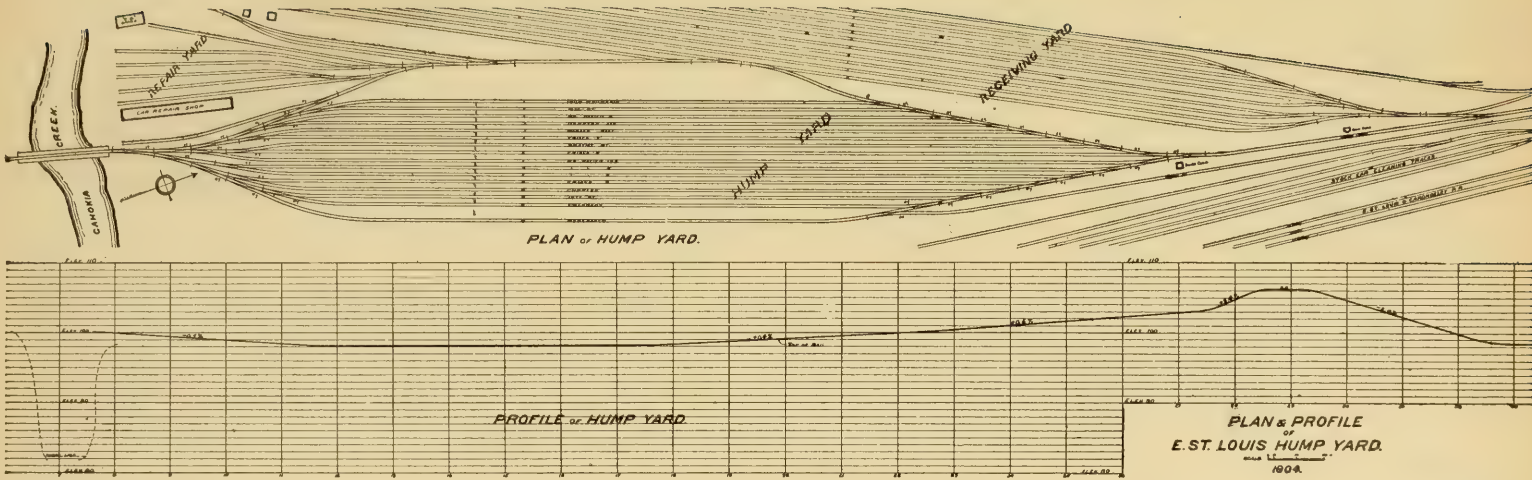


Fig. 2. Hump Yard, Plan and Profile.

spots would be most interesting in detail, and the results in strengthening as well as in stiffening the bridge against oscillation have been very gratifying. A description of the examination of the tubes of which the arches of this bridge are composed, certain holes being drilled and the inside of the tubes being examined by means of small electric lights and reflecting mirrors, as well as of the means adopted for carrying certain portions of the bridge by means of supplementary members while certain connecting pins, which had become corroded, were repaired, would also be interesting, but only this reference will be made to it. Many smaller steel bridges and trestles were also built at various points.

Following the construction of the main lines, the next thing was to provide largely increased freight storage and switching facilities to care for the large daily volume of freight cars handled within the yards and keep the main lines clear. In accomplishing this a great deal of new construction and rearrangement was necessary in the switching yards. Independent drill tracks were provided in numerous cases, where the yards had been drilled on such main lines as then existed.

Among the first work of this kind undertaken was the construction of an artificial gravity or "hump" yard at East St. Louis, of which a plan and profile is shown in Fig. 2.

In order to get accurate data as to the amount of switching actually done in this yard, an accountant was stationed near the drill track, and the actual time when each cut of cars began to pass, the number of cars, and the time when the last car was switched, was set down.

From the data thus obtained it was learned that the switching capacity of a yard of this character is not less than 100 cars per hour with a percentage of 80 switches to each 100 cars, almost every car in this switching having a different destination. Apparently this rate could be maintained throughout the 24 hours if the yard were large enough. The tracks of this yard, however, were not long enough to get the full benefit of the rapid switching, as the shorter tracks were very quickly filled up, and until they could be emptied the switching must be stopped.

Various alterations were made to separate and untangle conflicting lines of movement at the entrances to the various yards, and the yards in many instances were subdivided by constructing more than one drill track, thus enabling more than one engine to work at one time without interference one with another. These matters are more interesting when illustrated in detail

with a description from actual conditions of the lines of movement for which provision was made, and the method of subdividing the yards so that more than one engine could work continuously. Figs. 3 and 4 show the old and new arrangement of tracks at the East St. Louis ranging yard.

On a terminal property like this the question of interchange tracks for interchanging business with connections becomes one of first importance, and groups itself with freight storage and handling facilities. These interchange tracks are, under the usual railroad practice, in duplicate, each road furnishing a track on which it receives business delivered to it by the other. Properly located, these interchange tracks should be at the junction of the two lines, and each road should be able to make deliveries without going on each other's main line. The capacity of these interchange tracks to hold cars, the prompt and regular clearing of them, and the keeping of them clear as often as they are filled, is the most essential feature of handling the Terminal Association's business, and 90 per cent. of all delay and congestion experienced by the Association within the past three years may be traced to failure at the interchange tracks by one or the other of the parties to the interchange. To facilitate this interchange the terminal has recently built tracks, conveniently situated, at many points, among which may be mentioned the Valley Division of the Iron Mountain, the Southern, Louisville & Nashville, St. Louis & O'Fallon, Baltimore & Ohio, Vandalia, and Troy & Eastern connections with the Illinois Transfer in Illinois, and the Wabash on the West Belt in Missouri, which, with various arrangements that have been made at other points, will take care of a total of nearly 1,200 cars. This contributes directly to the free interchange of business, and means that where two years ago 1,200 cars were held over for interchange, they can now be delivered at once. This means 1,200 cars at one time, and with proper effort these interchange tracks could be handled two, or even three, times per day.

For the proper care of the Terminal Company's equipment, which consists principally of 99 locomotives, railway repair shops have been erected at Brooklyn, Ill., consisting of a power house, 11-stall machine shop, embracing boiler shop and blacksmith shop, with all necessary machine tools, transfer tables, wood and paint shop, store house, oil house, 16-stall roundhouse and complete coal, sand and water station.

So far, in increasing the terminal facilities, we have dealt with main lines, with freight car yards and switching capacity,

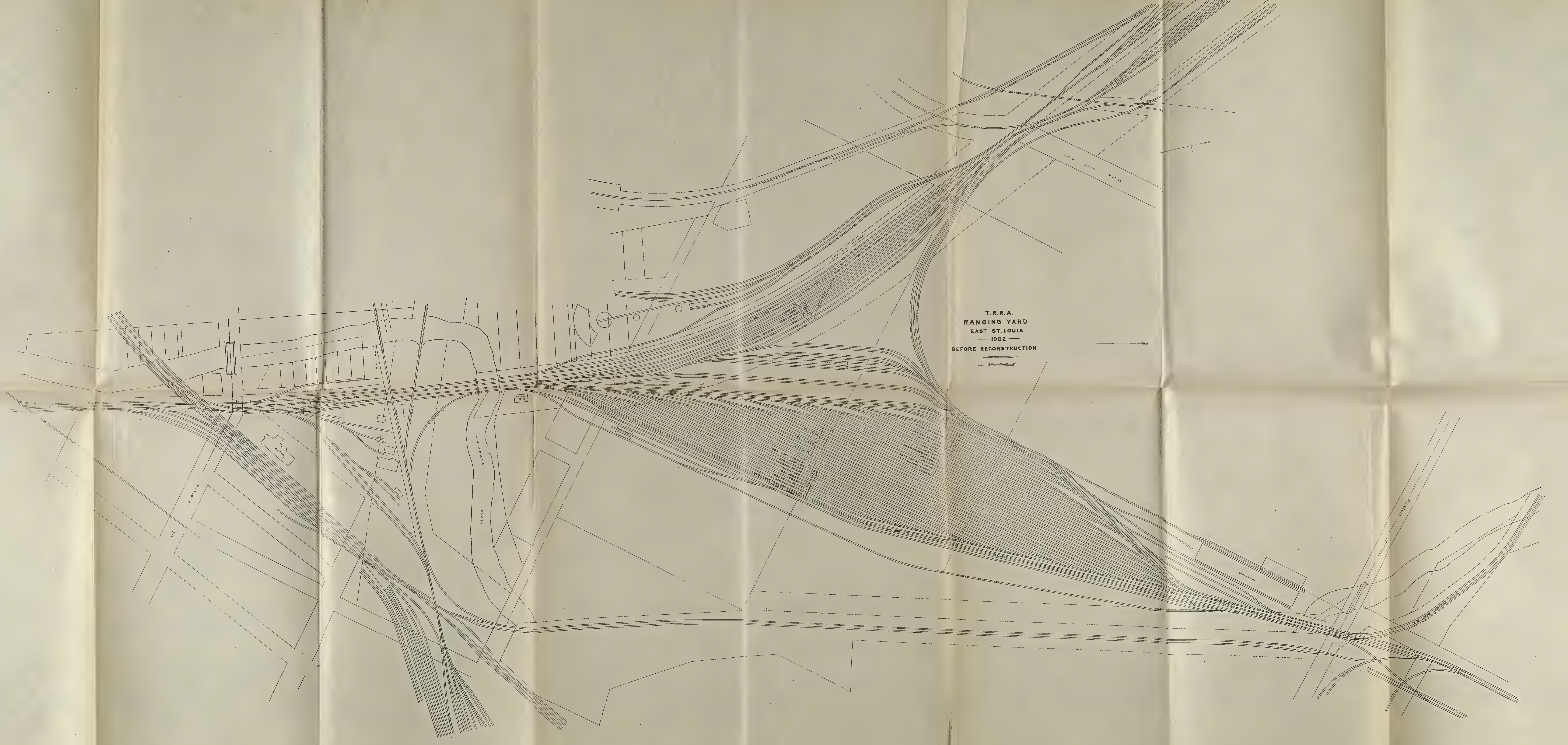


Fig. 3. East St. Louis Freight Yard in 1902. Scale 1″ = 200′.

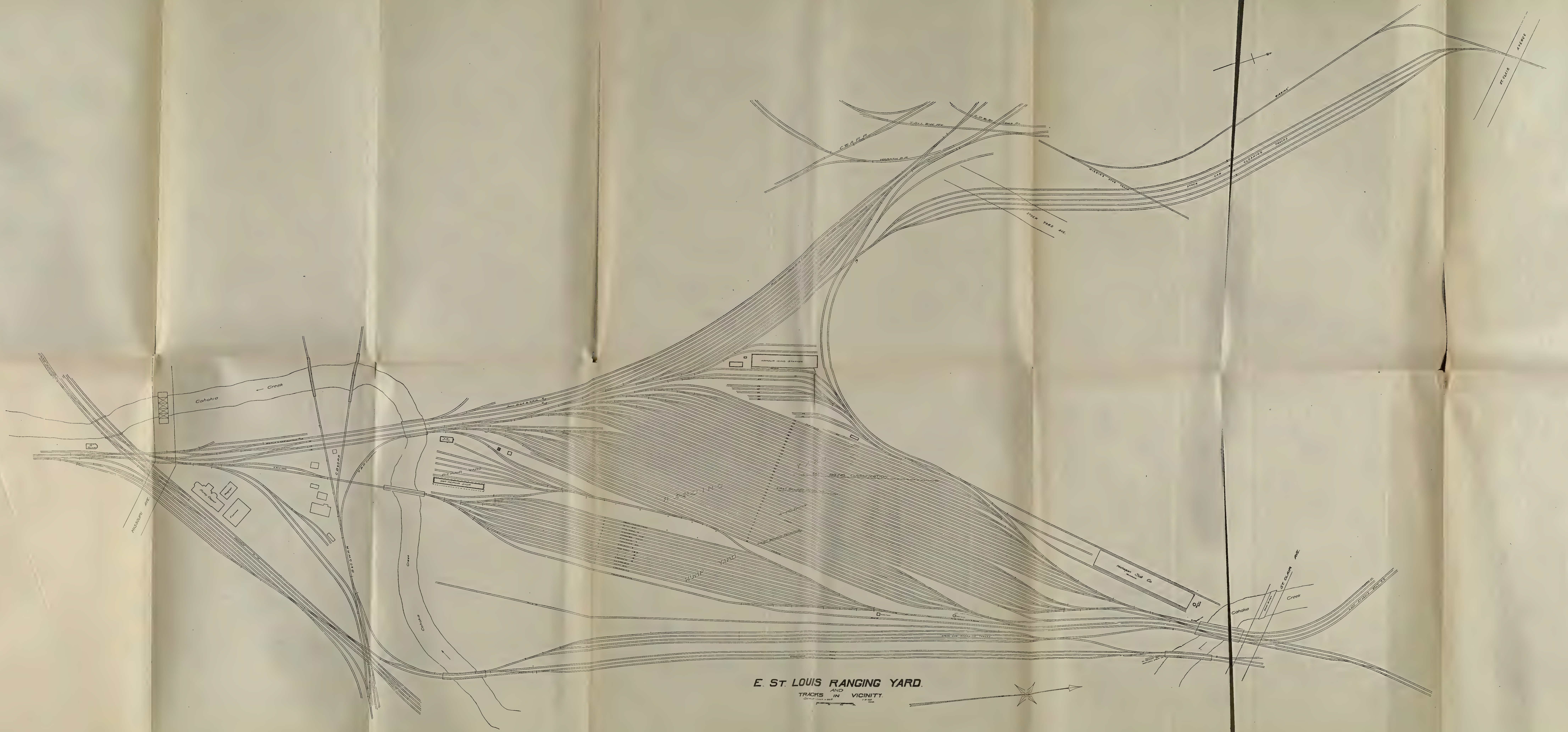
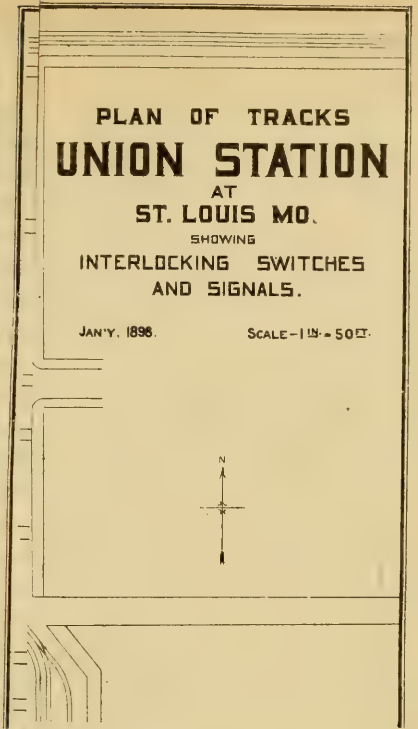


Fig. 4. East St. Louis Freight Yard as it now is — 1905. Scale 1" = 200'.


PLAN OF TRACKS
UNION STATION
AT
ST. LOUIS MO.
SHOWING
INTERLOCKING SWITCHES
AND SIGNALS.
JAN'Y. 1898.
SCALE - 1 IN. = 50 FT.
N

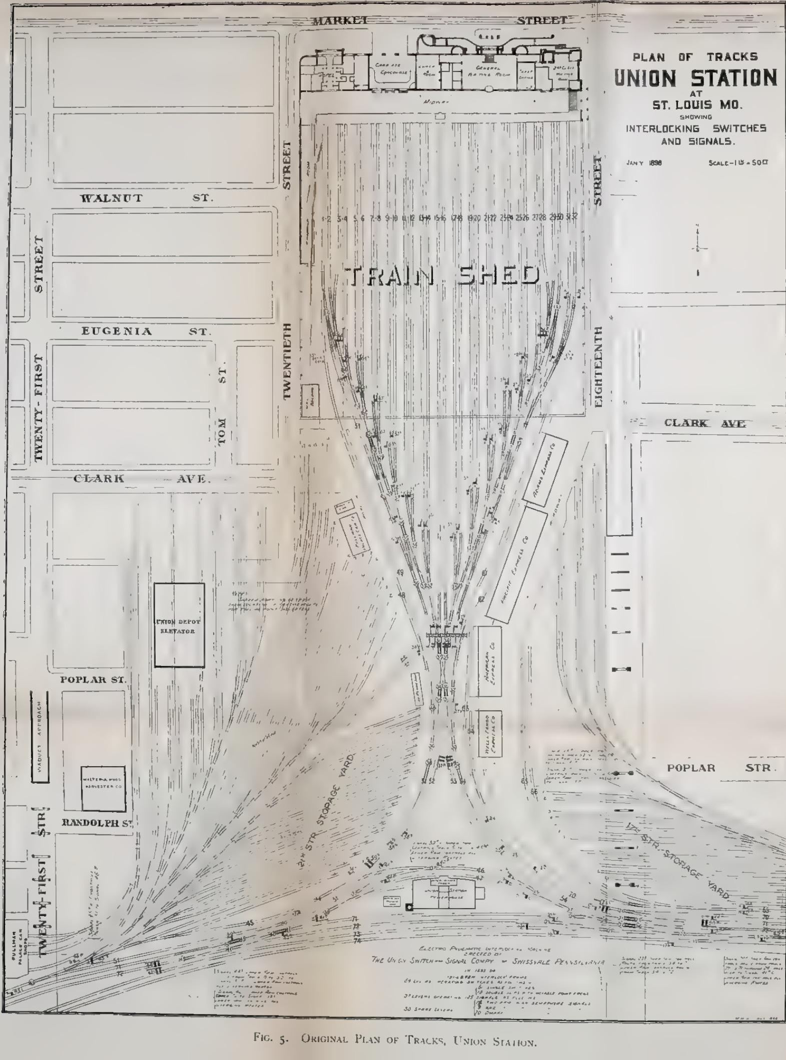


Fig. 5. Original Plan of Tracks, Union Station.

these being the foundation for all terminal work, and, having thus cleared the ground, the question of increasing the capacity of the Union Station was next approached.

It was obvious from the first that any effort to improve the track plan in front of the station would involve the most radical re-arrangement and extremely heavy expenditure. The question was therefore approached with the utmost gravity, but operations were demonstrating day by day that even the ordinary business of that period was in excess of the capacity of the track system. This was previous to the World's Fair, and the authorities of the Fair estimated that the attendance would be between 30,000,000 and 35,000,000 people, which, of course, would be largely in addition to the normal travel.

Obviously, therefore, something must be done, and the weighty interests involved determined the undertaking, although the expense from the outset seemed almost prohibitive.

By an examination of the old track layout at the station shown in Fig. 5, it will be seen, to begin with, that the express buildings had been brought down to within 75 ft. of the central axis of the train shed, thus constricting the "throat" in such a way that it could not be widened without moving these buildings.

Furthermore, there were the strictest limitations to what could be done due to the short distance, 1,103 ft., from the south end of the train shed to the private property of railroad lines to the south, which those lines considered indispensable to the conduct of their own business, and which the Terminal therefore could not secure. Further limitations were found on the east in the Eighteenth Street viaduct, and on the west in the Twenty-first Street viaduct, and even if there had been time to negotiate for alterations in these viaducts, which there was not, it was extremely doubtful whether the city would have consented to any alterations. In fact, in view of the reception which the Terminal Association met from the city when it asked for certain privileges from it, which are conspicuously trivial as far as the city is concerned, there is every reason to think that the city would have refused to allow any alterations. Therefore, all improvement in the track layout had to be made within the area bounded on the south by a line 1,103 ft. from the south end of the old train shed, on the east by the Eighteenth Street viaduct, and on the west by the Twenty-first Street viaduct. This gave an amount of room entirely insufficient for making an ideal, or even an approximately good, track layout, and

the result of all the study that could be brought to bear by those engaged appears in the new track layout, which, while not good, is, it is to be hoped, the best that could be secured within those limitations. The new track arrangement is shown in Fig. 6.

These changes, of course, involved the entire removal of the old interlocking plant (the largest in the world at the time it was built, only 10 years previous), and also the removing of the power house, which had been considered at the time of its erection, 10 years before, to be sufficient for many years to come. The largely increased demands on the power house also made it necessary to almost double the power to be provided; and it will be readily seen that improvements of the nature just described would be enormously expensive.

Furthermore, the time in which the work must be accomplished was known to be very short, and was shortened by negotiations with the city, which, although they finally came to nothing, had the result of crowding the work into an almost impracticably short time. The expense of doing this work so hurriedly was enormously increased; and no one who has been connected with any work in St. Louis during the period of the World's Fair will fail to understand how labor conditions also affected the cost of work done within that period.

The work was also thrown into the winter months and an illustration will show some of the difficulties encountered. In laying the track south of the train shed during last winter we found that the ground was frozen so that it would have been almost as easy to pick away flint rock as it was to get through the frost. Therefore the simple expedient was adopted of spreading wooden trash and splinters over large areas of ground and burning it the night before, to that by morning the ground would be sufficiently thawed to enable men to pick it. A large proportion of the track in front of the station was laid by this means.

Space forbids any mention of the details of the new 2,750 h. p. power house and permits only a reference to the interlocking plant, which is the largest in the world, controlling as it does 67 double slips, 91 switches and 287 signals from the three towers. The central tower contains the largest machine of 215 levers, 45 ft. 9 in. long, which is the largest in the world, the next largest being the one at Long Island City of 167 levers. The complexity of the track layout is shown by the fact that there are 1,827 possible routes through this plant, one lever (No. 190-L) alone controlling 146 movements. The system includes

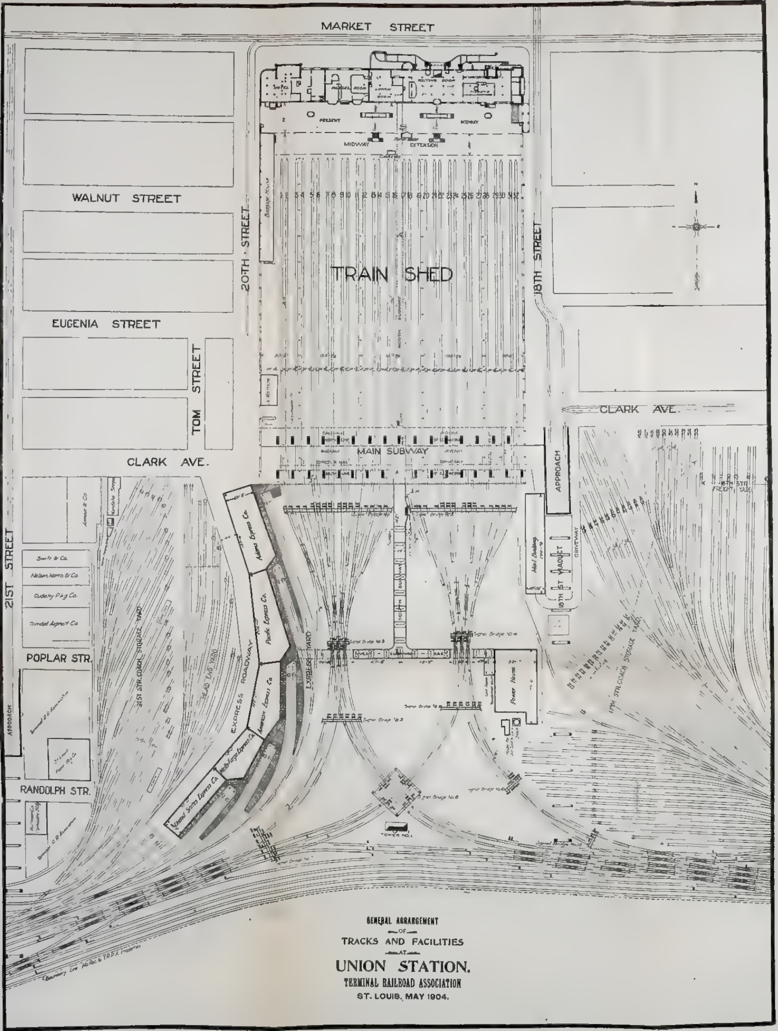


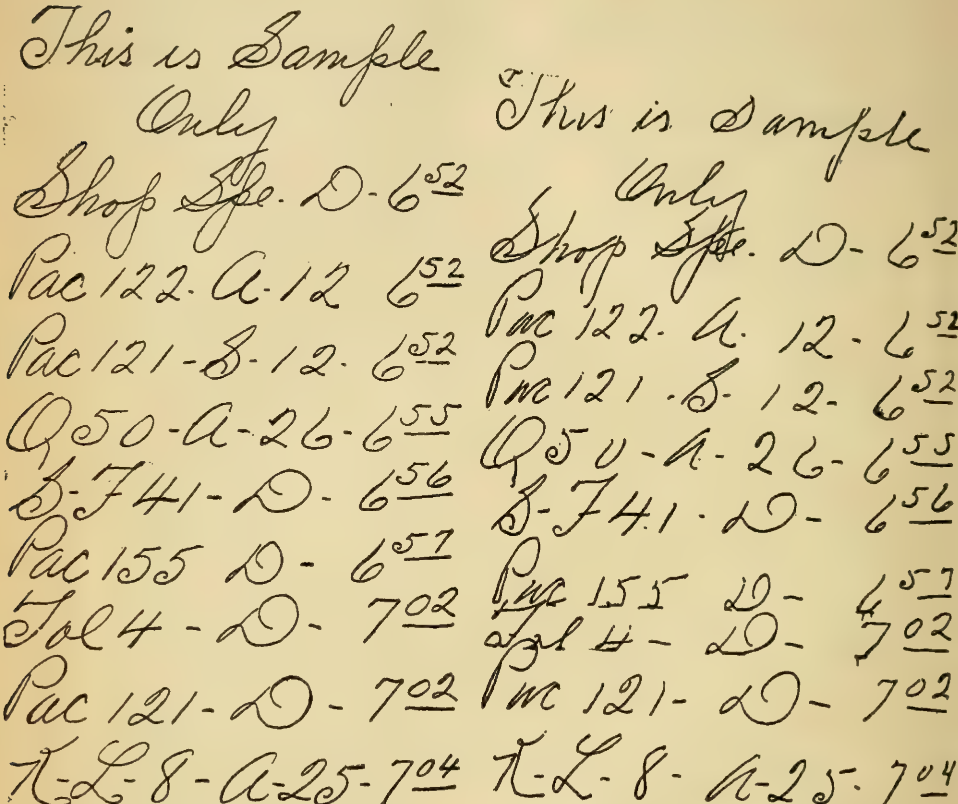
Fig. 6. Present Plan of Tracks, Union Station.

electric annunciators by which the men in the tower are informed whether any tracks under the shed are occupied by any car or engine, and by which the trainmen get a high-speed signal from outlying points, indicating that they may proceed at a high rate of speed to their destination in the train shed, the route being set up and the track clear, as well as electric inter-connection between the towers by which the coöperation of operators in each of two towers is necessary to control signals at the point where the interlocking from the two towers unites.

Among the items especially interesting on account of the novelty of its application, may be mentioned Gray's Telautograph, which is used for publishing and recording information sent from tower No. 1 to five points in the station, announcing the arrival and departure of trains. This is, as its name implies, an electrical reproducing machine, which reproduces from one sending station the actual handwriting of the operator at as many duplicating stations as may be required. Obviously, the current work of the station requires that many points be informed of the time and place of the arrival and departure of every train. The dispatchers on the property are located in Tower No. 1, and they get advice by wire as soon as any incoming train reaches any one of the numerous terminal junction points. That information is immediately published by the telautograph at the five points, namely, the station master's office, bureau of information, baggage master's office, baggage handling subway and the south end of the train shed, in order that everybody may be informed that, for example, Burlington train No. 8 was approaching and would arrive on track No. 17, 7.19 A.M.

This enables the bureau of information to tell the public when that train will arrive and on what track. It enables the station master to arrange his men to meet it. It enables the baggage master to send his trucks and men to the proper point and makes possible the proper disposition of men and trucks in the subway for handling the baggage, mail and express. This device is described in a pamphlet issued by the United States Patent Office, and was on exhibition at the World's Fair. The United States Government makes use of it to enable a range finder, stationed some distance away, to communicate with a gun battery, as it fills all the requirements of this most exacting service. It makes errors — except initial errors of the sender — impossible. It leaves an accurate record, it is secret, noiseless, visible, and it can be operated by any one who can write. So far, its application in the Union Station has given

absolute satisfaction and the derangements have been almost absolutely nothing. Fig. 7 shows a sample of its reproduction work.



As Written in Pencil at the Sending Station. **As Reproduced in Ink at the Receiving Station.**

FIG. 7. FACSIMILE OF TELAUTOGRAPHIC RECORDS. REDUCED ONE HALF.

Another interesting departure from ordinary methods is in the application of pneumatic tubes to the baggage service. The vast volume of baggage handled at the station made it impossible to concentrate the work of the checkmen or of the public, some of whom must see the baggage themselves, as so great a bulk as that comprised by the great number of large trunks, chests, etc., must spread over a large territory. Under the old method of handling the baggage, the checkman in many cases must take the passenger's ticket and hunt up a trunk in whatever pile it might be located, which might be several hundred feet away, attach check and bring duplicate to the pas-

senger, or the passenger might be required through some lack of identification to pick out the baggage himself.

Instead of trying to remedy this, the situation was accepted, and the separation of the checkman from the baggage was made final and complete. The baggage was taken into a subway constructed for the purpose across the south end of the train shed and delivered underneath the track from which it would finally leave, while the checkman was put into communication with an attendant stationed at the baggage, by means of a pneumatic tube which covered the intervening space separating the checkman from the baggage.

Study of the old conditions has also shown the long distance which the baggage had to be transported after it was checked, in order to reach the train. It was received in the old baggage house on Twentieth Street opposite Walnut Street and had to be trucked on an average nearly 1,200 ft. Not only that, but it had to be trucked across tracks at grade, and as these tracks were often found occupied by long trains or by arriving or departing trains, close connections were continually being missed. Accidents were also common, the baggage trucks being run into by incoming trains. By means of the subway this trucking is cut down to a very small percentage of what it has formerly been, and all danger of collisions averted. Some of the details of handling baggage in this way would be interesting, but it may be said that the plan was a success, and, in many instances, baggage under the new system was loaded on the train, after being checked, before the passenger could walk from the checking counter and get on the train himself. The baggage was never so well handled as was the enormous volume of baggage handled during the Fair, the number of pieces handled during that period being 1,739,000 as compared with 885,467 of the preceding year.

The large system of hydraulic elevators which raises or lowers the baggage between the subway and the train-shed level is also interesting. The room that could be occupied by the elevator platform was very limited and its shape was determined by the narrow train-shed platform of which it must form a part.

The elevator hatchways are protected by steel gates which rise 3½ ft. as the elevator descends, the motion of the gates being only half as rapid as that of the elevator, thereby minimizing the danger of any one being caught and injured by the gate. The elevators have a maximum capacity of 4,000 lbs. each, under a pressure of 600 lbs. to the sq. in., and with a 2,500 lb.

load a speed of 150 ft. per minute. They are, however, tested to 1,000 lbs. and can be run at that pressure with a corresponding increase in speed and capacity. (See Fig. 8.)

There are 37 of these elevators, — 18 being for baggage along the north side of the main subway, 17 for mail and express along the south side of the subway, and 2 for mail in what is known as the Post Office Annex.

The system of subways radiates from a main subway, which is 97 ft. wide and 601 ft. long, as shown in Fig. 9. Following my first intentions to discuss only the broader lines of this work, details of drainage and sewerage will only be touched upon. One of the problems of sewerage that had to be contended with arose from the fact that the city sewers underneath the subways are insufficient to carry off the heaviest volumes of water during periods of storm, and the sewers fill up to a height of perhaps 20 ft. above the bottom of the subway, giving a static outward pressure of water equal to about 9 lbs. per sq. in. To force the sewage from the subways into the sewers against this pressure Shone ejector pumps were installed in a sump located as shown in Fig. 9.

To facilitate the handling of passengers around the head house during the period of the Fair, a second midway, 50 × 570 ft., was constructed south of the old midway, for classifying and handling passengers when crowds were very heavy. Two wide stairways leading from the midway to the second floor of head house were installed. The ticket office was altered so as to form a rectangle enclosed within the waiting room, giving space for 36 ticket sellers. A toilet room with 88 water closets, 48 urinals, 34 wash basins and 58 private rooms with water closets, wash basins and hot and cold water, was constructed in the basement under the west end of the head house.

For the purpose of handling locomotives with unusual dispatch during the period of the World's Fair, especially locomotives of the lines using the station, there was constructed at Fourteenth Street a coaling plant for coaling locomotives, combined with ash handling machinery for cleaning fires, and facilities for supplying water and sand. This plant has a storage capacity for 1,000 tons of coals, raised by duplicate hoisting machinery. Its ash handling machinery will take care of fires from 20 engines at one time. Three engine houses of rectangular shape, with a total capacity of 61 engines, were also built adjacent to this coaling plant.

Having thus given an outline, and, at best, a brief one, of

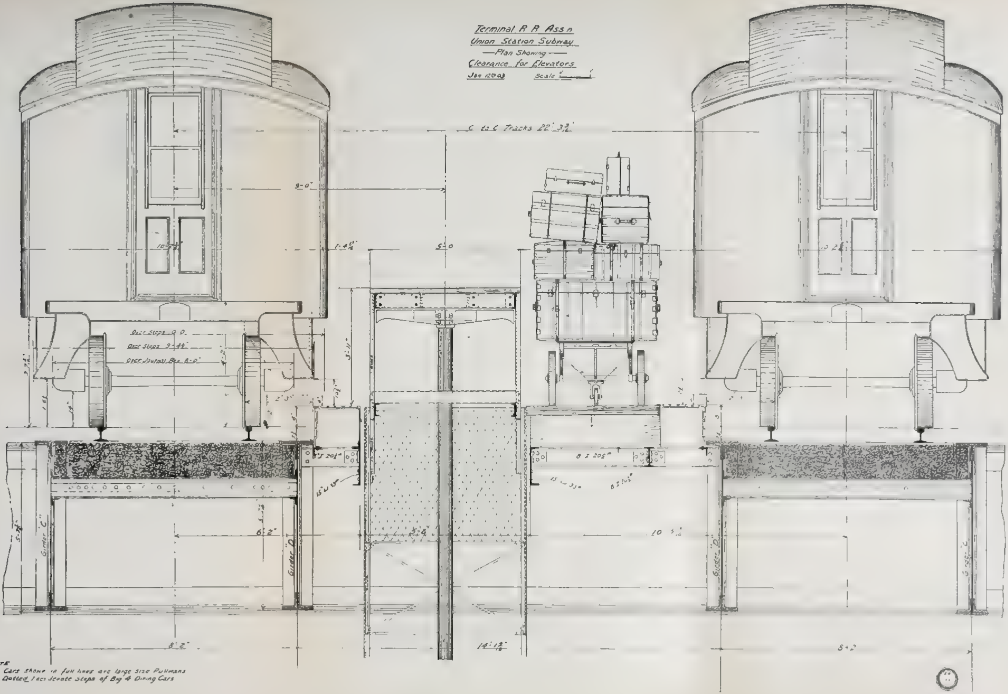


FIG. 8. SHOWING UPPER POSITIONS OF MAIN SUBWAY ELEVATORS WITH REFERENCE TO CARS ON ADJACENT TRACKS, AND TO TRUCKS ON TRAIN SHED PLATFORMS

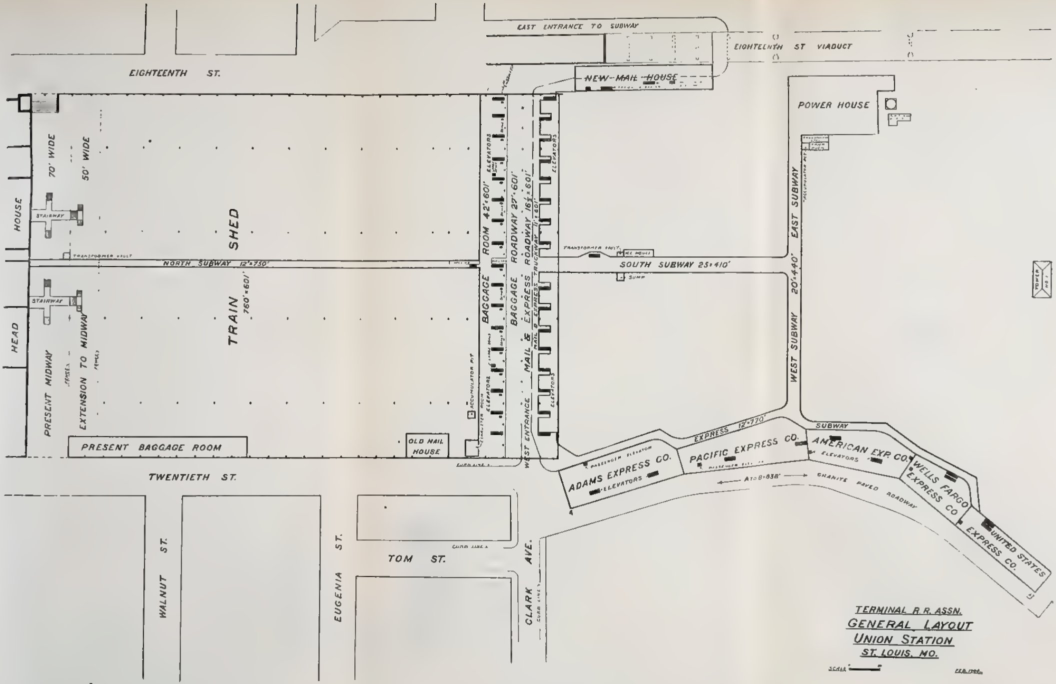


Fig. 9. Subway Plan, Union Station.

the scope of the work undertaken, it is sufficient to say that the terminal is, at present, equipped to handle all freight business as rapidly as the lines which now connect with it in St. Louis are prepared to deliver and take it away.

Also that as far as the Union Station is concerned, the operating officials have estimated that they could have handled an increase of 40 per cent. of the passenger business that came to them during the World's Fair.

SOME DETAILS OF RECONSTRUCTION WORK, ST. LOUIS UNION STATION.

By A. P. Greensfelder, Member of the Engineers' Club of St. Louis.

[Read before the Club, January 18, 1904.*]

Nearly two years ago, the writer read a paper before this Club, entitled "Proposed Improvements in St. Louis Terminals." This paper was printed in the Journal of the Association of Engineering Societies in January, 1904, was written at a time when the Terminal Railroad Association of St. Louis was in the midst of its planning and construction work, and merely outlined proposed plans of improvements. Most of the work mentioned at that time has been completed, although it was necessary to make some few changes due to lack of space and franchise privileges. Chief Engineer Daniel Breck has outlined some of the necessities for these improvements and additions and has stated some general principles governing the essential features of their design.

Mr. J. L. Armstrong, as engineer, Maintenance of Way, had direct supervision of this reconstruction work.

The territory covered by these reconstructions is so large and their magnitude is such, however, that it would be impracticable to describe the work in detail at all points. The writer, therefore, will confine this paper to that work under his especial charge, as assistant engineer, which has to do with the St. Louis Union Station and vicinity.

In planning the work, it was endeavored to obtain designs which would accomplish the desired results in a manner as nearly theoretically correct as possible. Then, when practical obstacles or conflicting conditions necessitated revisions, careful study was exercised to prevent such necessary modifications from being radical. It is manifestly impracticable, however, in adapting improvements to existing facilities to secure results as desirable as might be accomplished by entirely new constructions. Three eminent factors, therefore, governed largely in the design and execution of this work: first, designs as suitable as possible within the fixed areas and limiting conditions; second, their completion within the time limit, and, third, their construction without interference with existing traffic.

* Manuscript received March 6, 1905. — Secretary, Ass'n of Eng. Socs.

The improvements considered essential were, increased coach storage capacity; increased number of lead tracks into the station; main track rearrangement, permitting increased simultaneous train movement; yard readjustment, necessitating less switching; additional interlocking, permitting more rapid train movement; additional length of train-shed tracks; protection of longer trains by train-shed extension; additional express house and yard space; increased baggage storage area; elimination of grade crossing of trains and trucks; better facilities for handling baggage, mail and express by means of system of subways; widening of passenger concourse and adoption of double-gate system; pneumatic tube system for baggage check interchange between subway and checking counter; telautograph transmission of train movement information from yards to station house; increased counter length and space in the ticket office; increase in parcel rooms, lavatory and lunch rooms in headhouse; additional mail building; new and larger power house; a larger coaling station for cleaning, watering, coaling and sanding engines; and engine houses for care and storage of engines.

This work, for consideration in construction, may be divided as follows:

(1) Preparation of site.
(2) Temporary structures and false work.
(3) Excavation.
(4) Drainage.
(5) Masonry.
(6) Structural steel work.
(7) Buildings.
(8) Flooring and roofing.
(9) Track work and interlocking.
(10) Power generation and transmission.
(11) Lighting.
(12) Fittings and appurtenances.

In considering these subjects, the reasons for adoption of the various plans and methods will be touched upon and the work itself briefly described.

Preparation of Site.

In order to gain a proper conception of this reconstruction work, it is essential to bear in mind the difficulties which had to be overcome and the conditions encountered. After the first governing factor of the work — the design — had been

decided upon, there remained the other two factors, which were not so readily disposed of, *i. e.*, finishing the work before the World's Fair period, and taking care of existing traffic meanwhile. The situation was interesting in the extreme. At the time of beginning work in the field the traffic conditions were already severe, the facilities for handling business being even then inadequate, the main tracks constantly busy, and the freight and passenger yards overcrowded. The reconstruction plans were radical. New main tracks must be built where stood the old express buildings and power house; new leads must be laid cutting through the very center of existing yards; freight team yards must be removed to provide space for new passenger yards; tracks into the train shed must be raised and extended without interruption of service; old buildings must be torn down and replaced by new ones, larger in every respect and differently located; and a system of subways must be built beneath both old and new tracks.

It was evident that in order to finish the work on time it would be necessary to start at many points simultaneously. This seemed imperative, yet could not exactly be accomplished, because the new facilities must be built on space occupied by old ones, and the old ones could not be removed until proper provision could be made elsewhere for handling their business. The interdependency of each of the facilities involved considerations affecting almost every department of the railroad. The subway could not be finished until the train-shed tracks could be extended in their new positions; the train-shed tracks could not be removed from the old system of tracks until they could be connected to new leads over which trains could reach them from the new mains; these new lead tracks could not be built until the old express houses were removed; it was impossible to demolish the old express houses until new buildings could be erected on the west side, and the new express buildings being located in the center of the old Twenty-first Street coach yard, work on them could not proceed until coach storage space was provided elsewhere.

This merely serves as one example of the conditions encountered in the execution of the new plans. The same complications presented themselves on every hand. Car-repair shops had to be built in East St. Louis before like facilities at Eighteenth Street could be wiped out to permit the location of the new power house. The new roundhouse and shops being built at Brooklyn had to be finished in order to provide for

locomotives formerly handled in the buildings at Sixteenth Street, which had to be removed to permit construction of the new coaling plant. The three new engine houses were built up in the midst of and above the freight yard at Fourteenth Street, which could not be removed until tracks could be provided at other points.

It was impossible to provide temporary facilities in any large degree, because there was no vacant space available. Adverse city legislation prohibiting crossing of streets to reach certain property desired for the proper arrangement of facilities in this vicinity, and delay in securing any final legislative action at all, interfered largely with the execution of the work and necessitated changes in the plans. The only ground, therefore, added to that already used for railroad purposes by the Terminal Association in Mill Creek Valley — as the territory covered by the network of tracks from Grand Avenue to the Mississippi River is called — was a piece of land at Atlantic Street, between Jefferson and Ewing avenues, being then excavated for quarry purposes, a tract between Montrose and Compton Avenue, farther west, and two narrow strips secured from the Missouri Pacific and Wabash railroads between Eighteenth and Twenty-third streets.

A study of the entire situation developed the necessity therefore, for the arrangement of these tracts at Atlantic Street and Compton Avenue for coach storage and freight team yards, respectively, before much rearrangement could be accomplished nearer the station. Work was accordingly started on November 1, 1902, filling up the 25-foot hole in the quarry in this Atlantic Street yard, by scrapers and wagons, taking dirt from the points above grade; and on December 12, 1902, a steam shovel was started in Compton Avenue yard, excavating the 5- to 15-foot bank at that point. Progress in grading during the winter months was slow, and it was not until the latter part of the next summer that sufficient space had been cleared to lay a few tracks for coach storage at Atlantic Street.

Meanwhile, work for excavation had begun at the west end of the main subway. The old Twenty-first Street freight yard was being rearranged by cutting off a few car lengths in the end of several tracks and building a few new tracks transversely in the space thus vacated, so that the cars switched off the old tracks in the morning could be placed upon the new ones that same night. The old carpenter shops and the old Pullman Commissary Building at Twentieth Street were also demol-

ished. From this stage, the work progressed as rapidly as possible, adapting itself to the various circumstances and conditions as they arose, and was well completed in time for the extraordinary World's Fair traffic. A composite plan of the situation is shown in Fig. 1.

Temporary Structures and False Work.

In order to hasten the work at various points, it was absolutely necessary to remove certain of the old facilities before the permanent new ones were finished and ready, and in some cases, therefore, temporary facilities had to be provided. It was naturally endeavored to locate such temporary structures in positions where they would not interfere with the new work or hinder the operation of the old plant. Space was so limited, however, and there was so little area available for storage of new material that this could seldom be done.

Temporary coach repair tracks had to be provided at several places one after the other as the tracks could be spared, and the planking taken up and put down as needed. In the coach yards were located a number of repair shops belonging to the various roads handling their own coaches. The expedient was adopted of placing the repair tools and such material as these shops contained in old box cars and moving them about as desired. Where this was not advisable, as in the instance of the Chicago & Alton and Wabash, which had buildings located over the west subway, the structures were raised and moved bodily. In order to begin work on the east end of the main subway, it was necessary to demolish a portion of the two-story brick building of the Adams Express Company, and, to accommodate their business, a two-story frame structure, 50 × 80 ft., was built on the north end of their old building.

In order to excavate for the system of subways which is located directly under the tracks leading into the train shed, it was necessary to build considerable false work. Trestle work was built under each of the 25 tracks crossing the main subway, and under the lead tracks over the south, east and west branch subways. Three 30-ft. piles per bent were used for this temporary work, shown in Fig. 2, upon which were laid a 12 × 12 in. cap, 2-ply 8 × 16 in. stringers and 8 × 8 in. ties spaced 16 in. c.c. This false work had to be built under the very wheels of almost constant traffic, and rapid work was necessary. The piles, placed by a car driver run in on a track between trains, and working a few hours at a time, were 30-ft.

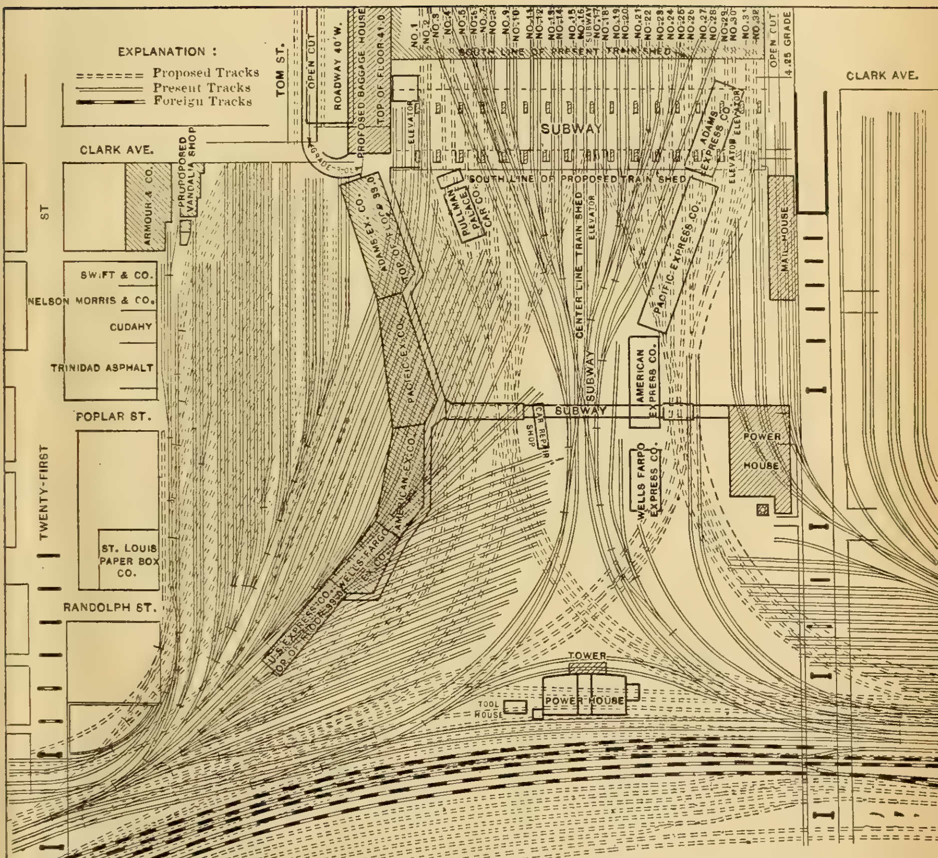


FIG. I. PLAN, SHOWING PRESENT AND PROPOSED TRACKS IN VICINITY OF UNION STATION. DECEMBER 8, 1902.

Scale, 1 inch = 300 feet.

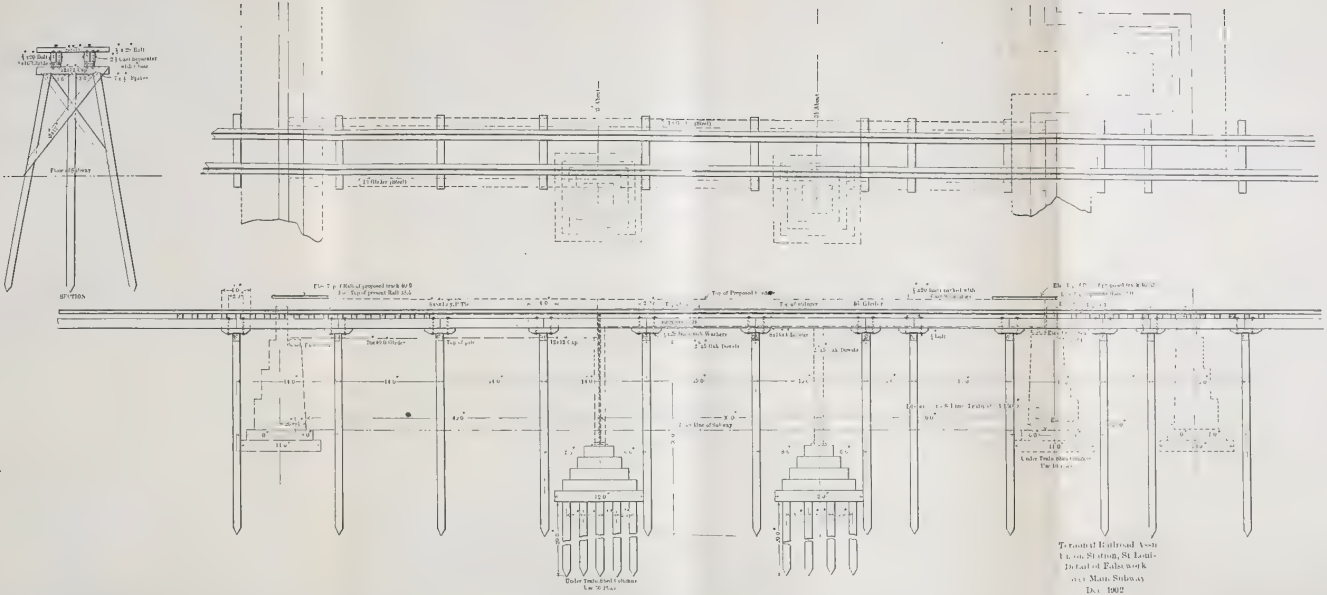


Fig. 2. Falsework over Main Subway.

rough hard-wood piles driven until their heads were below top of rail in spans of from 6½ to 15 ft., so as to miss the permanent masonry work.

In order to reduce the amount of excavation, save hauling of earth by using same for back-fill, to permit reconstruction of the large sewer in Twentieth Street according to a new profile authorized by the city, and to lighten the heavy grades of the wagon approaches to the subway, the tracks over the main subway were raised 2.5 ft. This was done without harm to platform levels, and eliminated the 0.5% grade halfway down the old train shed. As these tracks could only be spared for some hours at a time, the false work was framed ready, before the old rails were taken up. Excavation for the caps was then made, the pile heads sawed off, the corbels and stringers set, ties placed, spacing blocks set between the ties to prevent bunching in case of derailment, rails relaid and connected up to the old track, the interlocking rearranged and the tracks turned over for service again within the allotted period.

Permanent white oak 25-ft. piling was driven under the train shed and subway piers, after excavating to the subway floor level, by the same track driver on the false work above, using a sliding extension lead and following 28 ft. The last 10 ft. of following being through hard clay, considerable difficulty was encountered in withdrawing the timber follower from the ground, until a 16-in. block and falls, with a 1¼-in. hemp rope attached to the drum of the pile driver engine, was used.

Excavation.

Various methods were suggested and employed for excavating. At the power house, coaling station and engine houses, where the quantities were small, the only feasible method was by hand, casting the earth several times if necessary to load on flat cars placed on adjacent tracks. For the subways, express and mail building adjoining, covering an area of about 5 acres and involving the handling of over 125,000 cu. yds. of earth, the question was a greater one.

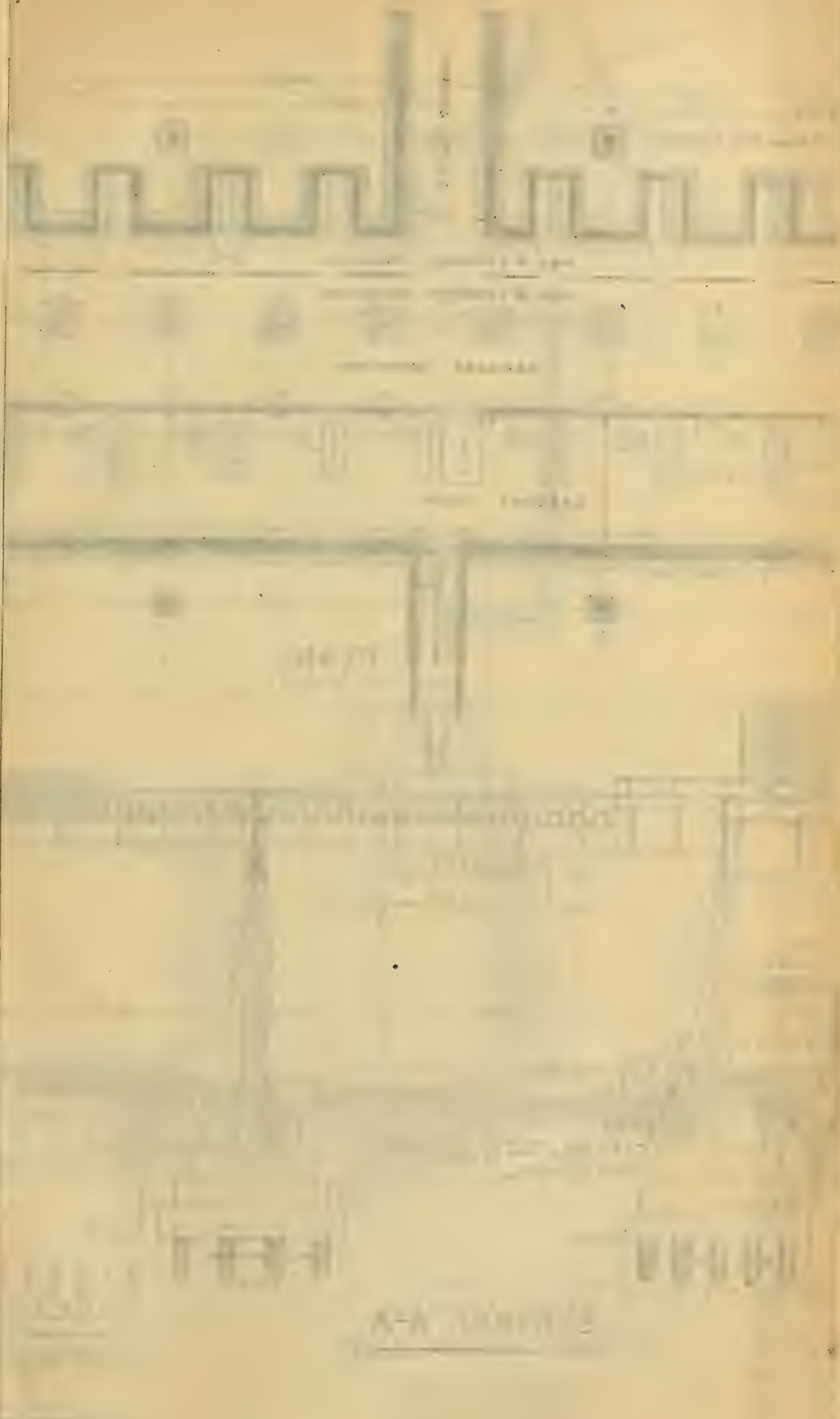
Where false work had been driven over the main subway the headroom was too small for dippers, and the bents would have interfered with steam shovel work, or an orange-peel bucket working from above. This latter plan, as well as any surface method of excavation, would have required the abandonment or use of two or more tracks, or have interfered with the leads into the train shed, which could not be permitted at

that time. These reasons, as well as the desirability of keeping construction trains from interfering with passenger traffic, led to the adoption of the method of sub-surface working.

Work was begun from both ends, on the west side on November 18, 1902, and on the east side January 2, 1903. Excavation was made by pick and shovel, loading into flat cars run in on temporary standard gage tracks, gradually lowering the cut until,when the exterior lines of false work were reached, the flat cars could clear the stringers. Headings were then made and the tracks gradually extended through the wide panels, the earth being also loaded from the sides, as the cars were placed. Three tracks were run from the west end and one from the east, and joined near the center. When the earth had been excavated casting distance away from the cars, wheelbarrows were put in service on plank runways nailed to the false work piles, and often 125 cars a day were loaded in this manner.

Previous to starting excavation, borings with a hand auger to depths of 30 ft. had been made all over the area covered by the subways, and showed 15 to 20 feet of loose filled ground overlying a blue sandy clay on the west, running into a natural yellow clay bank on the east and southeast portions of the site. This territory having years ago been covered by a lake or bayou known as "Chouteau's Pond" had been gradually filled up as the city grew larger. Little trouble was experienced from earth sliding, although some bracing fastened to the piling was used in places, especially during excavations for piers where pit framing was necessary to prevent movement of the oily clay or its sand bearing material. Quicksand was encountered in only one pocket, at the north accumulator pit, 25 ft. deep, between tracks Numbers 2 and 3. The concrete sides of the 10×10 ft. pit were then built from the quicksand surface up, and a $\frac{1}{2}$-in. sheet-steel cylinder, 9 ft. 6 in. in diameter, braced by circular $3 \times 3 \times \frac{3}{8}$ in. angles, was sunk, the material being excavated from inside this shell as it was forced down by screw-jacks. To retain the quicksand, a 24-in. concrete footing was then laid, a $\frac{3}{8}$-in. concentric steel cylinder, 8 ft. 6 in. diameter, placed inside the outer shell, and the space between the two filled with concrete to form a permanent ring in case the steel corrodes away.

Where the subways ran through the old express buildings, advantage was taken of the fact that these buildings rested on piles, to push the excavation under them, by the use of proper



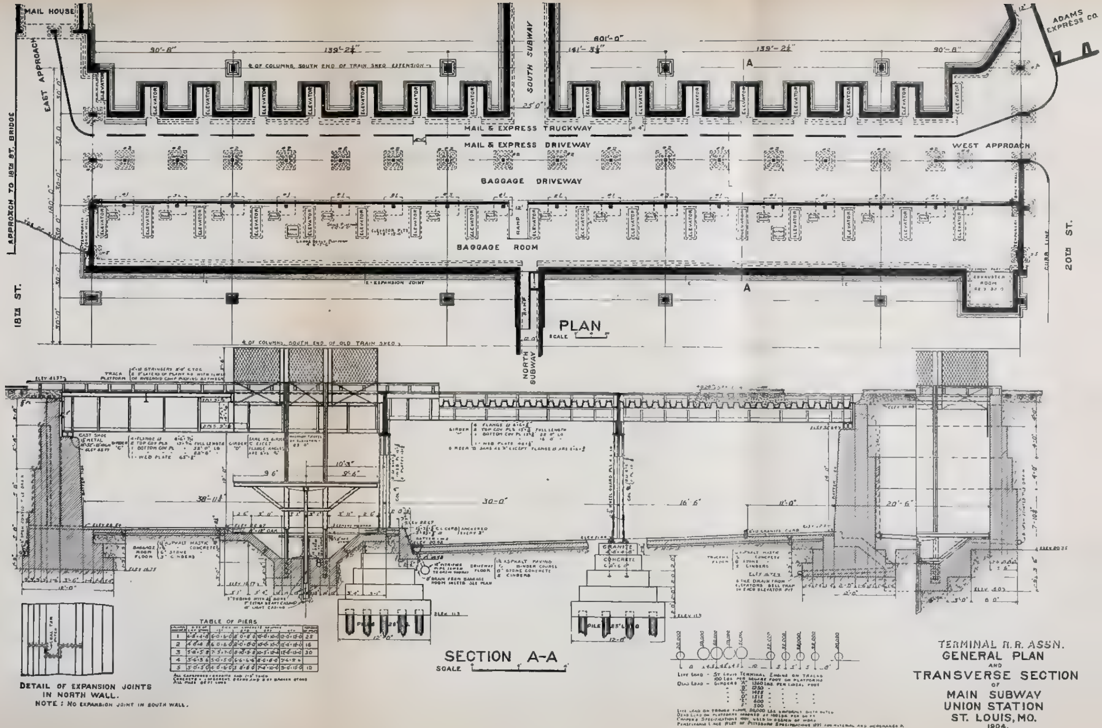


FIG. 3. DETAILS OF MAIN SUBWAY.

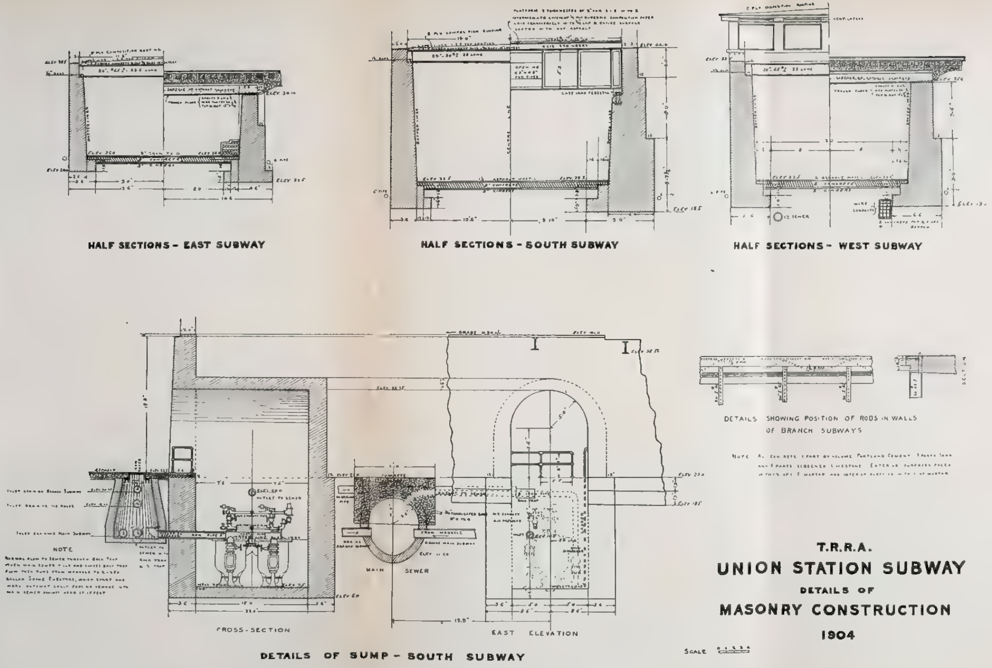


FIG. 4. DETAILS OF CONSTRUCTION OF SOUTH, EAST AND WEST SUBWAYS, AND OF SUMP IN SOUTH SUBWAY.

bracing. Incandescent lights were strung over the false work and excavation carried on in ten-hour day and night shifts. Five thousand cars were loaded, mostly during the winter months of January and February, 1903, and January, 1904. The basements of the five express buildings being on the same level as the subway floor, this block was excavated by steam shovel and diggers loading into wagons or cars, and by wheel scrapers. The steam shovel with a one-yard dipper and 100 men, loading into 35 wagons hauling 400 to 500 ft., often excavated in 10 hours over 1,000 cu. yds., of which 45% was loaded by the steam shovel.

Drainage.

The territory in this vicinity is drained into the city sewer system through the Twentieth Street and Camp Spring sewers, emptying into the 15 × 20 ft. Mill Creek sewer just south of the station. The 7 × 8 ft. oval brick sewer on Twentieth Street projected above the level of the basement floor, and made it necessary to rebuild both it and the intercepting branch where they joined under the Adams Express Building. A new profile and cross section were adopted, and, as the sewer was subjected to a floor load from above of 250 lbs. per sq. ft., and an interior head of 20 ft., a concrete steel design was selected.

Reconstruction work was also necessary where a 2 × 3 ft. sewer crossed the north subway under the midway. This was rebuilt in concrete, side and bottom forms removed, and a concrete expanded-metal slab roof slipped in place and cemented down. During construction work, the subways and buildings above the subway floor line were drained into city sewers, but pockets and pits had to be cleared by two small steam pumps.

The finished subway and express buildings are drained by a thorough system of 8-in. and 12-in. vitrified pipe leading to a manhole in the south subway. This manhole connects through a back trap with the city sewer, and with another outlet to two 250-gal. Shone ejectors, located in a 10 × 15 ft. sump 15 ft. deep, shown in Fig. 4. The normal flow is direct from the manhole to the city sewer, but when this main fills and closes the back trap, the sewage overflows into the ejectors which start and work automatically under 15 lbs. air pressure, and force water into the sewer main against a head of 20 ft. The sump, itself, and the two deep accumulator pits are drained of seepage water, when necessary, by small $4\frac{1}{2} \times 3\frac{3}{4}$ in. brass-

lined pumps run by compressed air and operated, when necessary, a few minutes daily.

Six-inch vitrified tile has been laid with open joints behind all masonry walls to drain them and prevent hydrostatic pressure from causing leaks through the mortar facing. The trough floor supporting the 32 tracks over the main subway is drained through holes in the center of each trough into an 8-in. 20-oz. copper gutter suspended below, which leads to a 6-in. tile run down the south wall of the subway, as seen in Fig. 5.

Masonry.

Concrete was the only masonry used in all this work. A mixture of 1 part by volume of Portland cement, 3 parts Mississippi River sand, and 6 parts of St. Louis screened limestone was used on all building foundations and work subject only to stable loading, while a 1 : 3 : 5 mixture was adopted to withstand moving engine loads.

The forms used for this work were made of $1\frac{3}{4}$-in. yellow pine tongue-grooved planed lumber laid horizontally and supported by 6×6 in. posts spaced 3 to 6 ft. c.c., depending on height of walls. These forms were used many times over and gave a smooth finish.

Concrete was hand mixed in some places, unloading the material from cars directly on to the mixing boards wherever possible, the boards being usually kept near places for deposit of the concrete. Where traffic conditions rendered it impossible to keep supply cars on hand at all times, the materials had to be stored at convenient points in order to keep the work moving. A 1 cu. yd. Ransome intermittent machine seemed to give better results than any other class of mixing. The materials were wheeled from the cars in barrows on to an elevated platform, dumped into the machine in the proper proportions, sufficient water added through a faucet in a gaged barrel, the machine turned a few times and then emptied into a trough, feeding the finished concrete by gravity into wheelbarrows below.

A 1 cu. yd. McCelvey continuous mixer, run by a small steam engine, was placed in a temporary shed at the west end of the main subway and supplied most of the concrete for the long north and south walls. Drop-bottom cars were brought in on an elevated trestle, and the materials emptied into storage bins. The rock and sand were then fed into gaging pans, the cement added, and the whole gradually dumped into the mixer below.

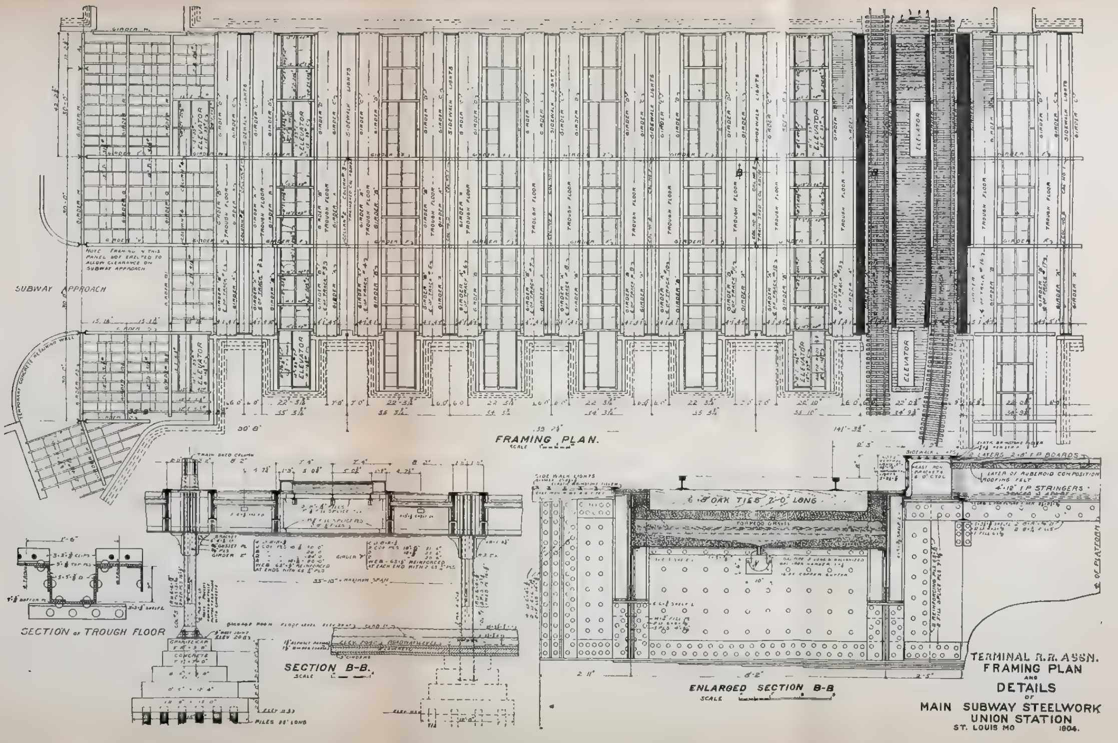


FIG. 5. STRUCTURAL DETAILS OF MAIN SUBWAY.

Two gaging pans were alternately used to keep the mixer supplied, but constant rate of feed was hard to obtain at all times, and this, together with the difficulty in correspondingly varying the water supply, gave resulting concrete not always of the desired consistency.

On all exterior walls of the subway, a mortar facing, $1\frac{1}{2}$ in. thick on the outside and 1 in. thick on the inside, was built up with the walls to make them water-proof. A 1 : 3 mortar was made, using washed Meramec River sand free of lignite. The metal plate system was adopted in placing this facing, using 10-in. plates 6 to 8 ft. long. The concrete was placed in 9-in. layers and thoroughly rammed with 12-lb. tampers until water flushed to the surface. This concrete presents a very neat appearance, although the east walls of the express buildings, which were spade-faced, are smooth as well. Work was carried on day and night, as many as 200 men working on concrete at one time for the subway and express buildings alone. Forty thousand barrels of cement were used in the two latter structures, and 14,000 bbls. on the adjacent buildings, including the coaling station, engine houses and interlocking towers. All cement was tested in the laboratory of the Terminal Association before acceptance and use on the work, and over 5,000 briquettes were made and broken. North Hampton, Pa., Atlas and Mitchell, Ind., Lehigh were the two brands most largely used.

The north and south walls of the main subway, seen in Fig. 3, were designed as ordinary abutments and retaining walls, but in the branch subways advantage was taken of the fact that the parallel walls were near together to adopt a more economical construction. As shown in Fig. 4, steel I-beams between the walls being necessary, upon which to build platforms or roofs above, and upon which to hang pipes below, these same beams were used to brace the walls against each other at the top. An 8-in. concrete sub-floor being necessary for paving these subways it was found that this same floor would prevent sliding of the walls at the bottom. The adoption of this plan cut the thickness of these walls in two and saved many yards of concrete. The walls were designed as beams fixed at both ends, and as the concrete was figured in tension, they were built in monolithic sections, 30 to 60 ft. long, each section being laid from bottom to top when once started. The sections are united by mortise and tenon joints, which permit expansion yet prevent leakage, although asphalt expansion joints were built every

100 ft. in the north wall of the main subway. In order to transmit the stress at the top of the walls to the I-beam struts, old rails or cheaper bent rods $1\frac{1}{2}$ in. in diameter were used. These branch subways were originally designed to carry pipes and wires, but were afterwards increased in size to permit trucking through them.

Sharp vertical corners were avoided at points where they might interfere with trucking, and curves with radii from 10 to 50 ft. were used, particularly in the express subway where there are many angles. By cantilevering out over the steel beams at the top of this subway, however, straight corners were carried up in the brickwork of the express buildings.

Capstones of Missouri red granite, 18 in. thick, were used under all train-shed and subway columns and on the walls where it was necessary to distribute the bearing load. James Stewart & Co. were the general contractors on the subways and express buildings. All other buildings were erected by George A. Fuller & Co. The subway masonry designs and general reconstruction plans for all work were executed by the Terminal Railroad Association, Mr. E. C. Dicke, chief draughtsman.

Structural Steel Work.

Large quantities of steel work were necessary to carry out the various plans, which for purposes of description may be divided into subway steel work, train-shed extension, coaling-station structure, power house and signal bridges.

Subway Steel Work.—The general arrangement of the main subway is shown in Figs. 3 and 5. Thirty-two tracks are carried on deck plate girders in 2 spans of 30 ft. and 1 of 42 ft. $2\frac{3}{4}$ in. These spans divide the subway into an express roadway, baggage-wagon roadway and a baggage storage and working room, to meet service conditions at this station. The girders rest on the north and south walls and frame into two rows of cross girders supported by columns spaced 35 ft. apart. A clearance of 14 ft. is obtained for the two streets, and 12 ft. in the baggage room. In order to deaden noise of trains operating over the subway, each track is carried by rectangular trough flooring resting on shelf angles riveted to stringers 8 ft. 2 in. apart. This centering requires the use of a 7-ft. tie, but admits a maximum amount of light to the subway from above. The troughs are 7 in. deep, made of $5 \times 3 \times \frac{3}{8}$ angles riveted together with $9 \times \frac{3}{8}$ in. horizontal plates, and were filled with hot asphalt-gravel concrete sloping from both sides towards the center where

a 1-in. nipple has been inserted draining into a copper gutter below. All steel work in contact with gravel was painted with red lead, and then swabbed with a heavy coat of hot asphalt to prevent corrosion. A 6-in. bed of fine clean gravel was then spread, and 12 in. of gravel ballast added.

The cross girders are very heavy, the $63 \times \frac{1}{2}$ in. webs being made in one piece and reinforced at each end with 2 shear webs, $63 \times \frac{5}{8}$ in., extending to the second stringer from each column. The flanges are made up of $8 \times 8 \times \frac{3}{4}$ angles and 18-in. cover plates, and the end stiffeners are four $6 \times 6 \times \frac{3}{4}$ angles. As the location permits no transverse bracing interfering with traffic below, small curved brackets were inserted under the cross girders which not only reduce the lateral vibration but add to the appearance as well.

The platforms between tracks are carried by light steel beams framed into the track stringers. Longitudinal expansion is permitted by slotted holes where the stringers rest on the north wall, and transverse expansion is provided for by slotted holes at every fourth column. The assumed live load on one trough is 20,000 uniformly distributed, while the stringers, cross girders and columns are designed for the standard Terminal 174-ton engines, and 100 lbs. per sq. ft. on platforms.

Tracks are carried over the branch subways on continuous rectangular troughs made up of $4 \times 4 \times \frac{1}{2}$ angles, $15 \times \frac{5}{8}$ in. horizontal and $20 \times \frac{1}{2}$ in. vertical plates, which are likewise filled with asphalt and gravel.

All material is open-hearth medium steel, except wrought-iron field rivets. Cooper's specifications for 1901 were used in design, and the specifications of the Western Pennsylvania lines of 1897 followed for material and workmanship. The steel work was designed and inspected by Brennecke and Fay, structural engineers, fabricated by the American Bridge Company, and erected by the Massilon Bridge Company. A total of 2,890 tons was required.

The erection of this steel work was governed largely by traffic conditions which permitted the use of only two tracks at any one time. To fit in with the new track rearrangement, erection had to begin on the center 8 tracks and was then successively started on west and east outside tracks to make connections with that center portion. The design required, first, the erection of a cross girder on its columns and the longitudinal stringers for two tracks with the adjacent platform between them. The steel work was stored at Twenty-third Street, and

brought to the subway on flat cars, and as scarcity of track room and heavy passenger business permitted the use of an additional unloading track only between the hours of 10 A.M. and 4 P.M., it was necessary to unload the cars within that time and place the steel in the subway below, where it could be reached by the erecting traveler.

The traveler moved from south to north on the trestle false work, erecting the 3 longitudinal spans in order. Pneumatic field riveting was used throughout, and as the steel was erected, painters, trackmen and carpenters followed immediately, as these two tracks and the platform serving them had to be entirely completed, ready for service, before the traveler was permitted to move to the next two tracks.

TRAIN-SHED EXTENSION. — In order to cover the main subway and protect the increased length of the shed tracks, under the new arrangement, it was decided to add to the old train shed an extension on the south of 180 ft., as shown in Fig. 6. It was deemed advisable to retain the same general outline and the same span lengths on the extension as on the old shed. The 180 ft. were, therefore, divided into 30-ft. spans for the exterior rows, and two 30-ft. spans and two 60-ft. spans on the interior rows of columns, fitting in with the subway column spacing. The most southern 30-ft. span is designed as a tower to provide against longitudinal wind thrust, while the lateral thrust is taken up by the exterior columns which are designed as vertical girders. The 60-ft. spans are connected by longitudinal trusses to carry alternate roof trusses, thus eliminating objectionable and more expensive columns and making a thoroughly well-braced structure.

Many changes were made from the old design details where improvement was desirable. The roof trusses are of riveted lattice type instead of the old patented pin-connected Pegram trusses. The adoption of riveted upper chord members and purlins, in preference to the old pin-connected, rod-trussed similar pieces with their multiplicity of parts, large number of small eye-bars, adjustable bent rods and quantity of boring for pin holes, decreased the shop pound price $3\frac{1}{3}$ per cent. and made their erection less expensive and more rapid. Expansion is provided for by slip joints at one end of the trusses instead of roller bearings which corrode and fill up with dirt. The new interior intermediate columns have fixed bases, as the column length is sufficient to permit bending due to temperature movements of the roof trusses without recourse to the old pin-connected shoes.

FIG. 7. EXTENSION OF TRAIN SHED.

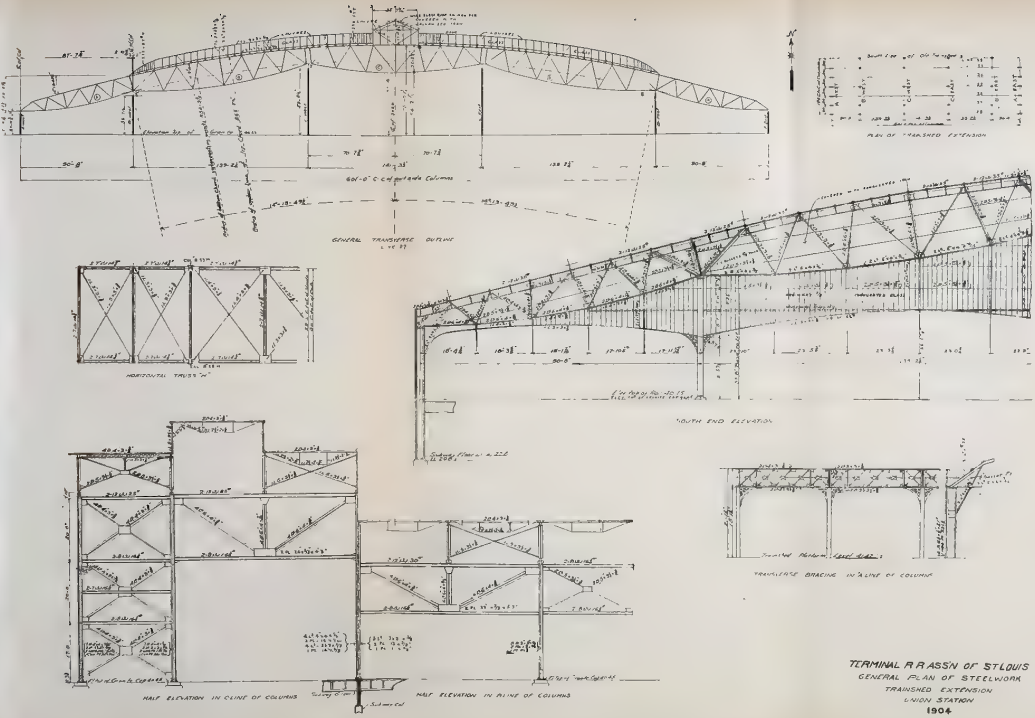


FIG. 6: STRUCTURAL DETAILS OF TRAIN-SHED EXTENSION.

FIG. 7. EXTENSION OF TRAIN SHED.

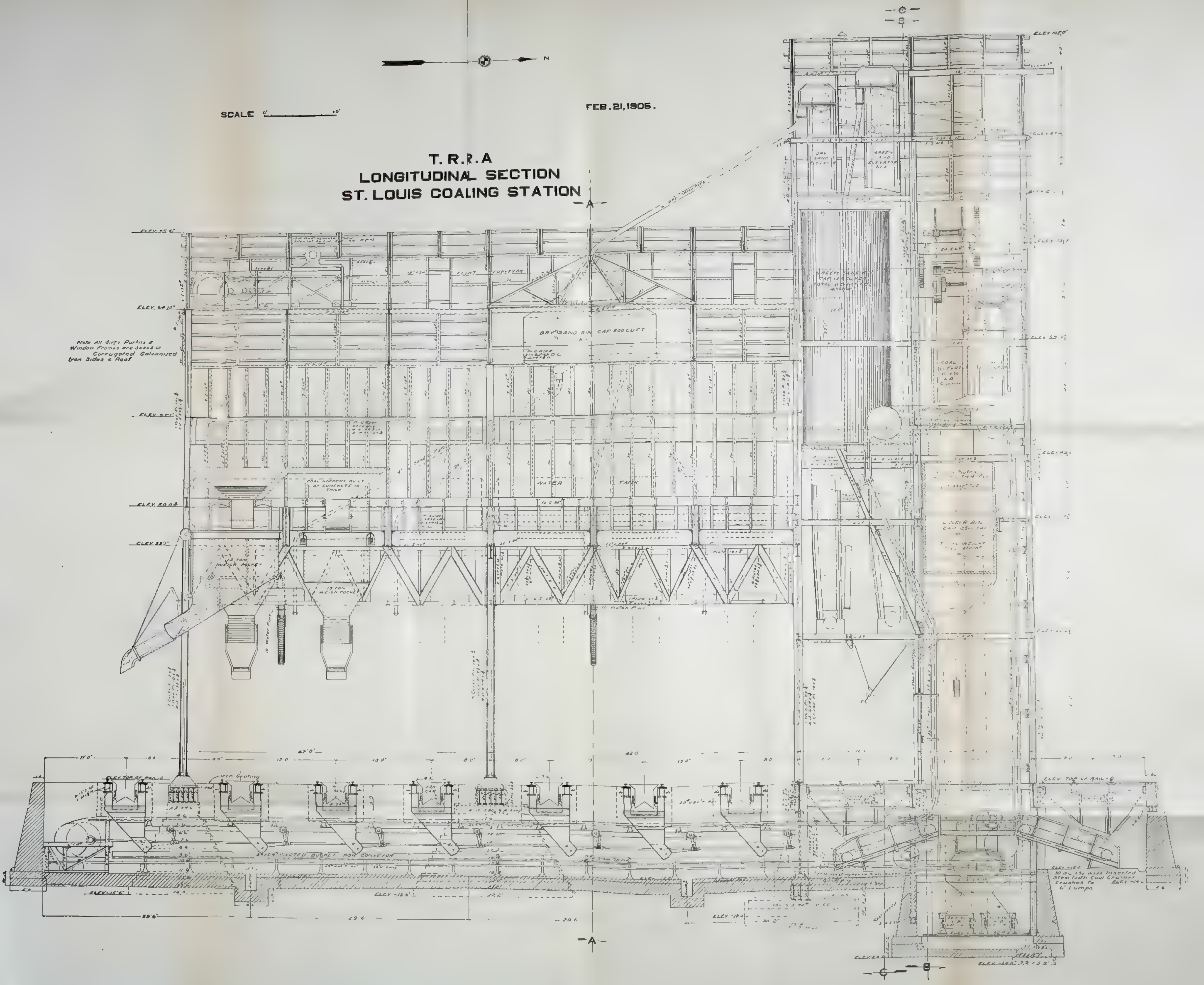


Fig. 8. Coaling Station, St. Louis

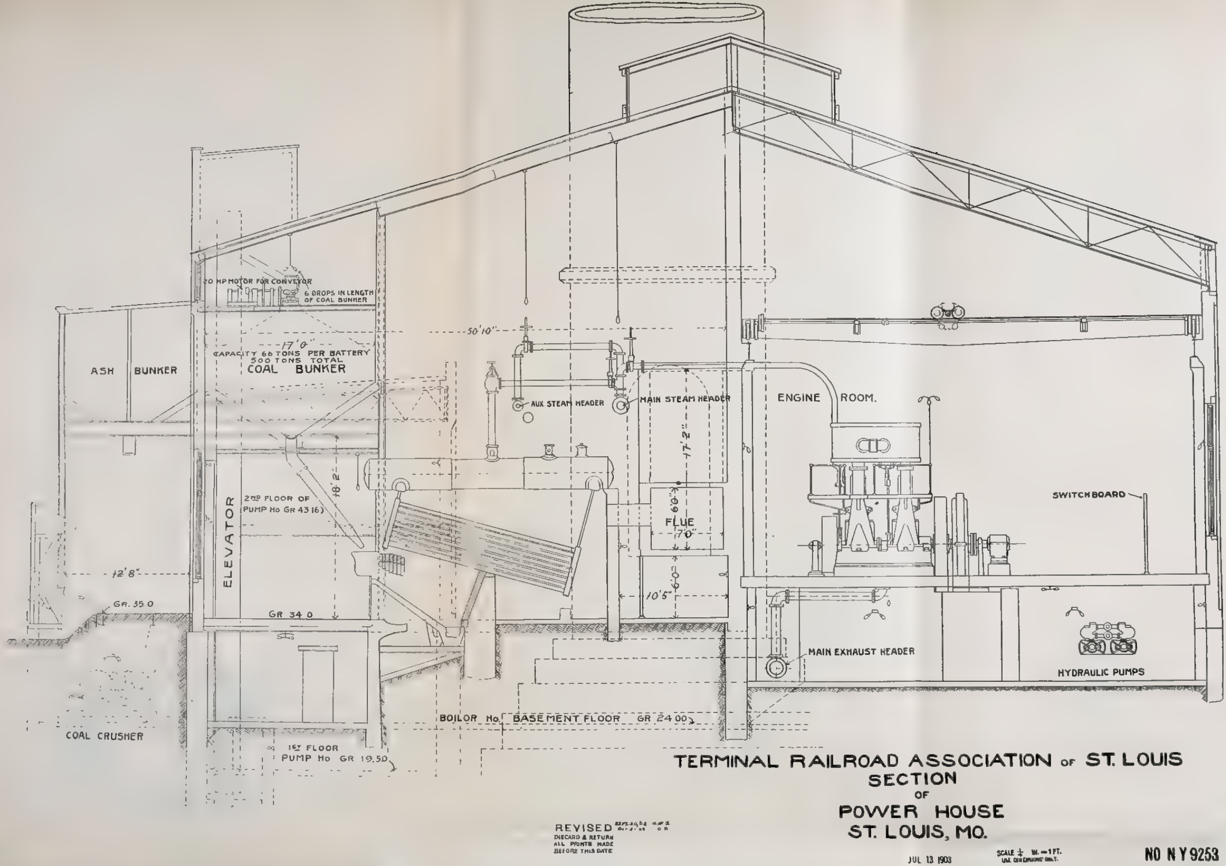


FIG. 9. SECTION THROUGH POWER HOUSE, ST. LOUIS.

The three 140-ft. spans were erected by means of framed timber travelers, supported by towers resting on platforms, between tracks, as shown in Fig. 7, while the 90-ft. end spans were framed on the ground and raised into position by a derrick car, which was also used to set the columns. No obstruction being permissible, the traveler bents cleared train movements, and head room was allowed in bracing over platforms to permit trucking. The 1,080 tons of steel work were brought in from the storage yard on flat cars at convenient times between trains and raised to the traveler platforms by boom derricks on top of them operated by steam hoists located on the track platforms below. Mr. J. C. Bland, consulting engineer, designed this work, which was made by the American Bridge Company and erected by the Massilon Bridge Company.

Coaling Station. — The coaling station sectionally shown in Fig. 8, located at Fifteenth Street, is a heavy box framework, 36 ft. wide by 115 ft. long, rising above ground 101 ft. and extending below the surface at the north end a distance of 20 ft. It is well braced against wind pressure in all directions, and designed to support the loads in the 1,000-ton coal-storage bin, the four water tanks 40 ft. long and 78 in. in diameter located in the angle formed by the sloping sides of this coal-bin, the two 75 cu. yd. cinder bins, two 125 cu. yd. green sand bins, two 30 cu. yd. dry sand bins, and the operating machinery. The coal and cinder bins are lined with concrete to make them fireproof, and inflammable material is eliminated throughout, the sides and roof of the building being covered with corrugated iron.

The lack of ground in this vicinity just west of the engine houses makes it necessary at this time to switch the Seventeenth Street coach yard over two of its tracks. This leaves four tracks free for the cleaning, coaling, sanding and watering of engines, or a capacity of about 20 engines an hour. Machinery totaling 180 h. p. is used for crushing, elevating and conveying coal, and for conveying and elevating cinders and sand. The entire station, with cinder pits, occupies only 12,860 sq. ft. of ground, and 425 tons of steel were used in its construction. The design is by Purdy & Henderson and the Link Belt Machinery Company.

Power House. — The power house shown in Fig. 9 at this station being a source of energy indispensable to traffic movement, it was deemed essential to build a fireproof structure. The house is 146 × 99 ft., built of brick, and has steel

roof trusses, a steel runway for a traveling crane in the engine room, and steel framing for boilers and the 500-ton coal bunkers in the furnace room.

Signal Bridges. — In order to locate signals in their proper places over the complicated track work, and minimize liability to accident through mistake in choosing the proper guiding indication, signal bridges were built so that each signal could be located over the right-hand rail of the track governed by it. Twenty-one bridges were thus required, varying in length from 28 to 250 ft., with a total length of 2,045 ft. or nearly two fifths of a mile, and weighing 313 tons. All bridges rest on two bents, except the rectangular bridges, seen in Fig. 10, in front of the interlocking tower, where four posts were used to prevent obstruction of view to leverman in the tower, and the two long bridges supporting the starting signals, just south of the train shed, which are upheld by three bents. Trusses are cantilevered out over the supports where locations would not permit end bents. The trusses are of the double-lattice, riveted type, dimensioned according to span length, while the bents have footings spread to give them stability. The essential features of design are that all bracing, both on the trusses and bents, is turned inward to avoid projections and improve the appearance; the truss chords are made of two angles and a plate, leaving no inaccessible places for corrosion from engine smoke or weather; and curved brackets are added to increase stiffness of truss connections to bents. Signals rest on top of all bridges except the starting bridges, where the signals had to be suspended in order to be seen inside the train shed, and are fastened to the top chords by means of connection angles. Wooden platforms are built on top of each bridge, reached by a ladder fastened to one bent, and have a light gas-pipe railing all around. These bridges were made by Stupp Brothers, Bridge and Iron Company, though designed by the Terminal Association, and erected jointly.

Buildings.

The entire group of new buildings in the vicinity of the station are of substantial construction.

The express buildings, seen in Fig. 10, are designed about 60 ft. wide to handle the business received at one side of the house and delivered at the other. The first floor is laid 4 ft. above top of rail on the east side to permit direct trucking into cars, and the roadway on the west side was built 3 ft. below this level to permit ready unloading from wagon beds. Electric

FIG. 10. EXPRESS BUILDINGS AND SIGNAL BRIDGES.

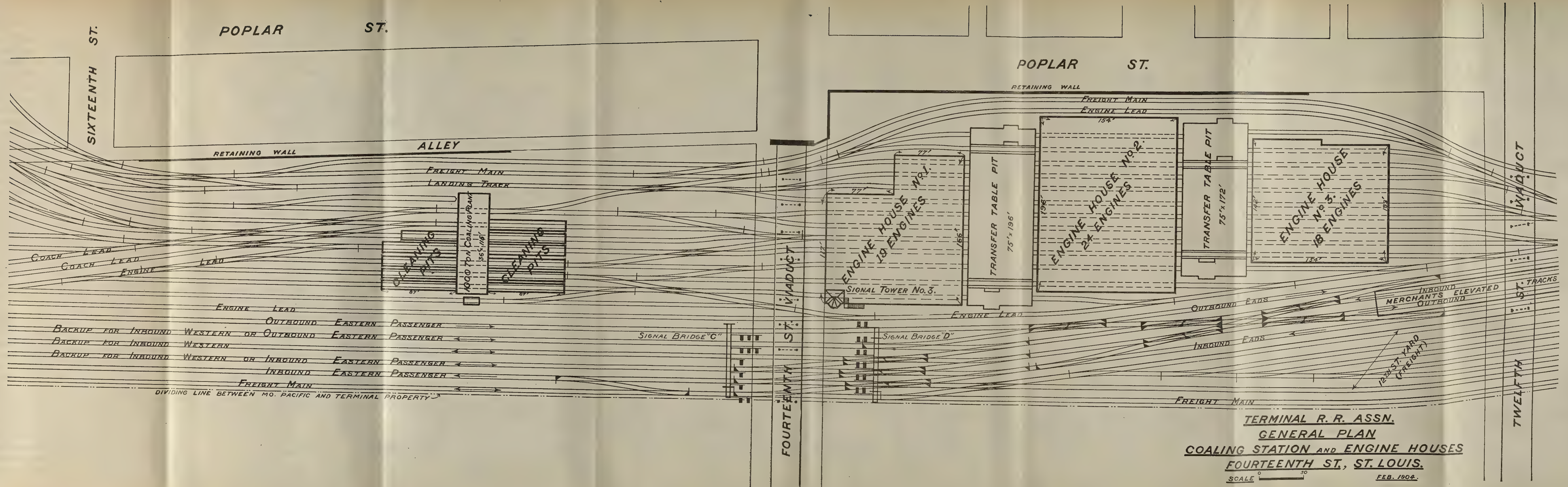


Fig 11. General Plan of Facilities for Handling Locomotives in Connection with Union Station.

freight elevators 6 × 16 ft. connect this floor to the basement at subway floor level. All the buildings have two floors, and the Pacific Company has three, upon which are located the general offices and storerooms. The total floor space in the 5 buildings is 152,900 sq. ft. Electric passenger elevators are run between all floors. The timber construction in these buildings as well as in the mail building, is of the heavy, slow combustion warehouse type, as designed by Eames & Young, architects. The trucking floors are covered with $\frac{7}{8}$ in. maple, while the 11-ft. exposed platforms on the west side are finished with $\frac{7}{8}$ in. oak, although glass awnings are built above them. The Adams building was erected, complete, in 90 days.

The mail building erected is a structure with three stories and basement, adapted to the needs of United States Post Office Department. The west end is fitted up as offices and working rooms of the Railway Mail Service Department, while the main transfer service use the rest for distributing rooms. This building is connected with the city post office, over a mile away, by two 8-in. lines of pneumatic tubes, which carry 15,000 to 20,000 lbs. of mail daily in carriers holding about 500 letters each. Second-class mail is received from wagons in the basement, raised on elevators to the various floors and redelivered below by chute to trucks, which carry it up the south line of subway elevators to cars on the shed tracks. Use of these pneumatic tubes and the subway trucking service permits transmission from the city office to within six minutes of leaving time for trains from the station.

The power house, of Fig. 9, is divided by a longitudinal center wall into engine and boiler rooms. A basement under the engine rooms provides space for hydraulic pumps and steam piping, while a similar arrangement under the boiler room permits the use of mechanical cinder-handling machinery, and contains the pumps and heaters. Independent of the power house is built a 200-ft. stack of Alphons Custodis radial brick, 11 ft. inside diameter at the top. An adjacent house also contains tanks and cooling coils for compressed air service. This house, 37 × 20 ft., has its sides covered by galvanized iron louvers to permit circulating air to reach the cooling coils, and an air intake stack is constructed with a dust pan below, through which air is furnished the compressors in the power house.

The three engine houses located between Twelfth and Fourteenth streets, as shown in general track plan of Fig. 11, are rectangular in shape and are served by transfer tables. The

limited space made such unusual design necessary, as roundhouses of sufficient capacity to serve the same number of engines through turn-tables would have required 30 per cent. more of valuable space, which was also not available. The use of two transfer tables on each pit between the houses, and direct connections to all tracks in the end houses, make engine movements exceptionally rapid and positive. The transfer tables are 75 ft. long, running on 5 rails in the pit at a speed of 125 ft. per minute when loaded with 150 tons, and 300 ft. per minute when light, and are operated by 35 h. p. A. C. motors. The three engine houses are 154 ft. wide and accommodate 61 locomotives. Washout pits served with water and air are located under the tracks, and a small shop is installed in the center house for light repair work. The roof trusses in these houses are very light, of Howe type, and, being located between tracks where transverse movement is unnecessary, they were built very low, which considerably cheapened the cost of the buildings. For the use of engine men a two-story service building was erected northwest of the engine houses. This is equipped with first-class toilet, locker and bunk rooms for their accommodation. On the first floor also a storeroom and a fire-proof oil room have been built.

Flooring and Roofing.

In order to facilitate trucking over the subway system, the basement floors of all buildings were built at the same level as the branch subways connecting with them, as shown in Fig. 3. The main subway is divided into two roadways, and a baggage working room, raised 2 ft. 3 in. above them, to facilitate the unloading of trunks from wagons backing against its protecting curb. An 8-in. granite curb is used in the south roadway to separate trucks from wagons handling mail and express matter. Concrete sub-floors laid on cinders were built in the subways and buildings, covering an area of 157,000 sq. ft.; and a wearing surface of granitoid 3 in. thick was placed on top where light service was expected, and asphalt was used where exposed to trucks and wagons. Asphalt mastic $\frac{3}{4}$ in. to $1\frac{1}{4}$ in. thick was used under the express buildings, the branch subways and the baggage working room, while asphalt concrete of $1\frac{1}{2}$ in. binder course and $1\frac{1}{2}$ in. wearing surface was applied on the main subway driveways. Although the main subway is covered by the train shed, snow and rain blowing in from the south end, or through the louvers above, and leakage from locomotives, had to be provided against. Ruberoid composition paper was

therefore laid between two layers of platforming, and the glass-work in place was made water-tight. The branch subways are covered by 1:2:5 cinder steel concrete, with wooden ventilators at every third panel between I-beams, both being roofed with 5-ply composition and gravel.

The train-shed extension is sheathed with $1\frac{3}{4}$-in. tongued and grooved yellow pine, and covered with 1,050 squares of Carey's magnesia felt roofing. This roofing is guaranteed for 10 years, and is much cheaper both in first cost and maintenance than the old tin roof eaten away by sulphur fumes from the smoke below. Ordinary slate roof is laid on most of the buildings. On the power house, however, book tile covered with cinder concrete was used as a fire protection, instead of wooden sheathing. The flat roofs of the engine houses are covered with 5-ply composition and gravel.

Track Work and Interlocking.

In order to increase freedom of train movement through the Union Station yards, it was decided from the first that a radical rearrangement of the old track system would be necessary. The two main tracks were increased to seven, and the one four-track throat into the trainshed was widened into two groups of three tracks each, thus diminishing the ratio of shed tracks per lead from 8 to $5\frac{1}{3}$, as shown in Fig. 1. Freight was separated from passenger, and both from engine and switching movement, thus largely increasing the range of simultaneous parallel movements. The train-shed capacity was increased from 225 to 330 coaches, by lengthening all tracks to uniformly hold eleven coaches instead of an average of seven, and a minimum of four. This permits spotting trains on any track, and was accomplished by using 15 per cent. of the old shed area wasted in the old design, and extending the tracks across the main subway, without increasing the lead curvature above 14 degrees. Switching connections and alternate routes in case of derailment at any point are obtained by the use of many double slips and cross-overs. No. 7 frogs were the lightest which could be fitted within the limiting territory, and for cross-overs on the shed leads curved frogs were designed to prevent extreme curvature. Rail for curves over 10 degrees was curved in the shop.

All inbound trains are backed into the station, so that by handling the train as a unit, switching movements to turn engines or replace the various cars in their proper order for

out-bound trains, are eliminated. This also places the baggage, mail and express cars so that they can be reached by trucks without interfering with passengers, and so that they can be switched out promptly with the road engine without waiting to remove the passenger coaches, which are often allowed to remain in the shed for several hours before they can be removed to the yards for cleaning and storage.

Twenty-two hundred tons of 100-lb. rail have been laid within the Union Station interlocking limits. The tracks under the train shed total 6.84 miles, while the entire mileage devoted to passenger traffic, including storage yards, with an increased capacity from 275 to 650 eighty-foot coaches, has been increased over 100 per cent. from 19 to 39.3 miles, covering 73 acres of ground.

This new system was built without greatly interfering with the constant traffic on the old tracks, although much of the new work was laid almost under the wheels of moving trains. Before the destruction of the old express buildings, the new western leads had been built and gradually put into service as the tracks were laid in their new positions across the subway, by making temporary connections to the old tracks, and, as the various obstructions were removed, the new trackwork was pushed forward, connected up for use of traffic, and finally took the place of the old mains and leads.

A new interlocking system was necessary for such a radical rearrangement as was made, and as the old plant was gradually cut off piece by piece, the new was extended and used for traffic. Both the old and new systems were electro-pneumatically operated by the Union Switch and Signal Company system, but until the new machines were finally connected up, the new switches were thrown by compressed air through valves operated by hand keys, moved by switch tenders on the ground. The machine in central tower No. 1 has 215 levers, of which 181 levers operate 48 double slips, 65 switches and 194 signals, and is the largest in the world. The work done by such a machine controlling 1,827 possible routes, is evidenced by the fact that it is the equivalent to 800 mechanical levers, and that 3 levermen took the place of 51 switchmen when the plant was thrown into service, at which time there was a daily movement of over 400 trains.

The large machine is divided into sections corresponding to certain track connections, and so arranged that the levermen need not pass each other as they work. In placing these

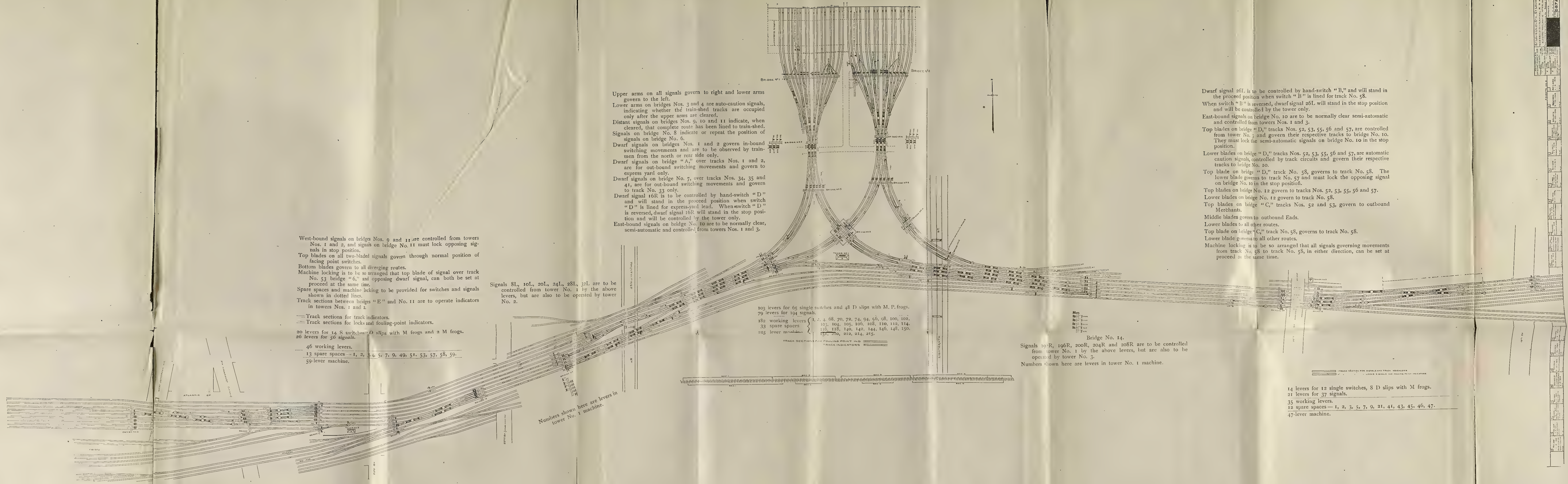


Fig. 12. Union Station Interlocking Plant.

machines in service, the expert operators had so familiarized themselves with the new plant that no trouble was encountered in any way. All fouling track sections are circuited with controlling signals, while track indicators in tower No. 1, and indicating signals on the throat signal bridges, show the presence of any train on train-shed tracks. Repeating signals are used where sight is interrupted, and distant signals permit rapid train movement. Electro-pneumatic air whistles, which can be operated from the towers, are also used to expedite train movements by calling the attention of train crews to signal indications. Push buttons are installed on the shed platforms, so that conductors can signal the train director when they are ready to start. Fig. 12 shows the track arrangement as interlocked. The signals have 90 degrees travel and are electrically lighted with 20-watt, 110-volt lamps.

Power Generation and Transmission.

The power house was built on ground not adapted for other purposes, and in a position located centrally as regards distribution. Power is furnished for electric lighting, elevator operation, coal-handling machinery, interlocking plants, building and car heating and car cleaning. Traffic conditions imperatively require that this power house be in constant service every minute of the day and night. With this in view, duplication of all essential generating units is absolutely necessary; and the equipment design made such provision. The capacity of the old plant was doubled and 2,750 h. p. can be generated in the 10 water-tube boilers furnishing steam at 250 lbs. pressure. Automatic stokers are fed from the overhead coal bunkers, to which coal can be furnished through a coal crusher having a capacity of 30 tons per hour, if the coal received is not already crushed. In the engine room are four 350 kw. 2 ph., 1,100 v., 7,200 alt., a. c. generators direct connected to vertical cross-compound,. marine-type engines, which furnish all electricity for power and lighting. Duplicate 62 kw., 125 v., d. c. excitors connected direct to compound single-acting engines furnish excitation to the larger units. Two 200 kw. rotary converters transform the a. c. to 520 v., d. c. for elevator service. Two air compressors, with a capacity of 2,180 cu. ft. of free air per minute to 100 lbs. pressure, furnish power to interlocking system and for car service.

The switchboard of 31 panels controls all electrical output. Three hydraulic elevator pumps, delivering 120 gals. of oil per

minute against a difference in pressure of 750 lbs., are located in the basement. In the pump pit are located the usual complement of pumps and heaters. The engines are non-condensing, due to economical use of exhaust steam for heating the adjacent buildings and headhouse during seven months in the year, and large pipes, with proper returns, are run through the subways to reach the various structures. High-pressure steam is required for car heating; and air, steam and water are piped throughout the various coach yards. Electric transmission is through lead-covered cables placed in tile duct laid in the subway, and by rubber-covered cable on poles through the yards. Alternating current is transmitted at 1,100 v., and converted through transformers at various points to furnish power to 50 odd motors.

Lighting.

The main subway is lighted from the surface during the day through platform glasswork $\frac{7}{8}$ in. and $\frac{5}{8}$ in. thick made by Dauchy Iron Works, while the branch subways are lighted by skylights above them. During the night the main subway is electrically lighted by 70 two-glower 100 c. p. Nernst lamps, operated at 220 v. on a 3-wire a. c. system. The branch subways are lighted by 2-cluster incandescent lamps hung from the roof.

The train shed in daytime receives light through its vertical glass curtains hung at both ends, and from the longitudinal and transverse glass lanterns on its roof. The total glass area in the entire shed, including the midway roof, is 125,000 sq. ft. At night the shed is lighted by rows of multiple a. c. arc lamps on 3-wire system, suspended over the platforms.

The yards are illuminated by series arc lamps supported on poles, while both arc and incandescent lamps are used in the buildings. Westinghouse, Church, Kerr & Co. installed the complete power plant.

Fittings and Appurtenances.

Elevators are used in the main subway to carry mail, baggage and express trucks to the platforms above, as shown in Fig. 3. As these elevators are operated by the inexperienced truckmen, some simple style of mechanism was essential, and as there was no space within the steel work or on the floor which could be spared for operating machinery, a direct lift type of hydraulic elevators was adopted, using oil as a transmitting medium. The platforms are 5 ft. × 19 ft., and while they occupy half the width of the baggage platforms at track level, there is still room for a truck to pass on the other side. There are two elevators for each pair of tracks, and where-

ever feasible these two elevators were placed along side the same track in order to minimize possibility of accidents which might occur to passengers leaning from moving trains. The elevators can be operated from below or above, but, if desired, they can be locked at the platform level so that they cannot be operated from the subway.

The three operating pumps are located in the power house and a duplicate system of main-pipe lines runs up to the main subway, where it connects to a closed circuit embracing each elevator, so that in case of accident to the piping at any point, service can be given from another direction. These pumps are automatically controlled by governors connected to two weighted accumulators, which start and stop the pumps as the service varies. The working pressure is 600 lbs., while a back-pressure of 40 lbs. for balancing the weight of the elevator platforms is obtained by connection of the suction pipes to a tank on the train-shed roof. A reserve tank of 14,000 gal. capacity is connected to the pipes at their lowest points in order to drain the system in case of leakage or accident. There are 35 of these elevators in the subway and 2 in the mail building, with a rated capacity of 4,000 lbs. and 2,500 lbs. for a speed of 150 ft. per minute.

There are 10 two-ton freight, 6 ft. × 16 ft., and 6 one-ton passenger elevators, 5 ft. × 5.5 ft., in the 5 express buildings, 2 in the mail building and 3 in the headhouse. All electric elevators are operated by motors of multipolar type, compound wound, receiving d. c. of 500 or 230 v., and were furnished by the Louisville Elevator Company.

Conclusion.

Numerous conveniences such as the telautograph system between interlocking tower and station, a pneumatic tube system for transmission of baggage checks from subway to baggage rooms, scales for weighing of baggage, etc., were installed for the betterment of service in the various departments, but they cannot be detailed here. Changes were made at the station headhouse, in the midway and at various other places where conditions required it, but at this time only such points are mentioned as seem to have some unusual or special feature in their design, application or construction. The endeavor has been to refrain from being drawn too much into detail which would interest only the specialist in his own class of work, and to present rather a description of the adaptation of various materials to the work in hand.

ALUMINOTHERMICS.

By E. Stuetz.

[Summary of a Lecture before the Civil Engineers' Club of Cleveland, February 14, 1905.]

The term aluminothermics is now recognized as the name of the science which utilizes the reducing qualities of aluminium in the arts.

It is essentially a new discovery, as the metal itself can only be said to have been discovered in 1827.

Its reducing qualities were only recognized to their fullest extent, and put to useful purposes, by Dr. Goldschmidt, who discovered that suitably prepared metallic oxides, when mixed with finely divided aluminium, would undergo self-combustion once the reaction was made to start in one place, and that this reaction would communicate itself, without supply of heat or power from outside, to all surrounding particles. The heat produced through the reaction of aluminium on the oxygen is about equal to that of the electric arc. One of its most prominent characteristics is that the time necessary to complete a reaction is practically independent from the quantity of the mass undergoing it. Fifty lbs. and 500 lbs. will burn down in practically the same time — about 20 seconds.

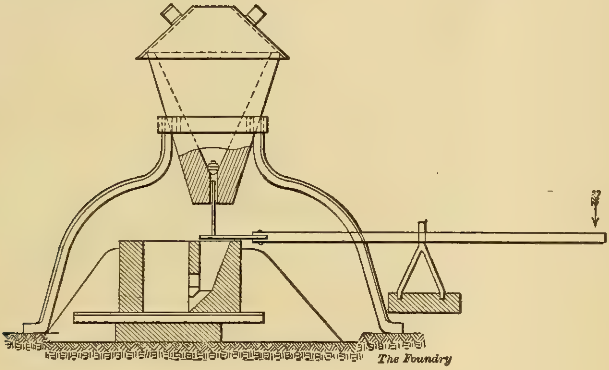
The chemical reaction takes place in a crucible. The thermit, a grayish-black powder, is ignited by putting a fusee into a small pinch of ignition mixture (peroxide of barium). By this reaction the oxygen is made to combine with the aluminum at a temperature of about 3000° C., leaving a very pure iron at the bottom of the crucible, covered by a lighter but bulkier layer of slag,— aluminium oxide, or so-called corundum.

The process has two main divisions as far as its application is concerned. The first concerns the metallurgist, the second the engineer.

To the first division belongs the production of pure metals free from carbon, such as chromium and manganese, molybdenum and ferro-vanadium. For ferro-titanium a very important and special application has been worked out for foundry work. Some of these metals are in extensive use in steel works in the United States of America.

The second division may be briefly summarized in the word "welding." The most extensive use of the welding process is

in connection with the continuous rail for trolley lines. Since the manufacture of thermit was started in the United States in July of last year, some fifteen towns have put down trial tracks, and are now watching the effect of the cold weather on these joints.



CRUCIBLE AND MOLD,

Which must always have a gate, so that the thermit steel does not impinge directly on the part to be welded. The crucible sitting in a ring supported by a tripod is tapped by driving up the pin and washers with which it is closed or "plugged."

The main recommendations for this process are, cheapness of equipment, simplicity of execution and effectiveness of work. The equipment consists only of refractory earthenware or sand mold and magnesia-lined crucible. Both molds and crucibles the trolley lines can make in their own shops without skilled labor. The weld is made by fitting the mold carefully round the joint and luting the contact lines with clay so that no liquid iron may escape, and placing the crucible exactly over the runner of the mold. The thermit is then ignited, and when the reaction by which the pure iron is separated out is complete, the crucible is tapped from the bottom. The liquid iron of a temperature of nearly twice that of ordinary liquid steel dissolves the rail ends, and welds itself with them into one homogeneous mass. The welding is automatic, no skilled experience being necessary to observe the moment when welding heat is reached. Sufficient thermit iron is run to form a shoe round the welded joint, which has thus a strength much beyond that of the rail itself, as has been proved by numerous official tests.

The electric conductivity of the rail is perfect. Great lengths of third rails have been connected by welding a short iron bridge on one side between the feet across the joint.

The principles described for welding trolley rails are equally

applicable to welding any other massive iron or steel pieces, in all kinds of industrial plants. One of the most effective jobs done in this connection was welding the fractured stern post of the Hamburg-American liner *Sevilla*, 9,000 tons. About 7 cwt. of thermit were used, the steamer was laid up for only a few days, and she has made several trips to and from Europe to Argentine.

Broken locomotive frames are now welded by thermit without dismantling the engine. It has been found that quite effective welds have been made without taking the engine out of commission more than fifteen hours.

Iron pipes can also be welded. As, however, the heat of the thermit iron would burn through any thin-walled iron object, the process here is reversed. The slag, aluminium oxide, is impervious to liquid iron, and coats with a thin layer any solid object it touches. The slag is therefore poured into a mold round the pipe joint and surrounds the iron as the white of an egg does the yolk. The weld is here entirely due to the heat and the pressure of a suitable set of clamps. The operation can take place anywhere, *in situ*, and there is no wear and tear of packing to make good.

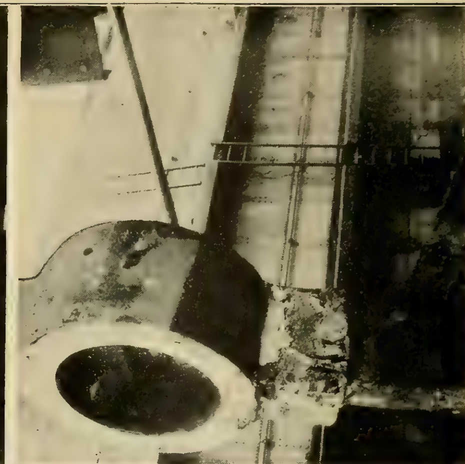
A separate application is that by which titanium, a most valuable purifying addition to iron and steel, is introduced into these metals while still in liquid state, fresh from the furnace. The titanium is introduced as titan thermit into the ladle by holding it in a can at the end of a shank below the surface of the bath. The result is greater fluidity, an automatic poling action, denser grain, and increased tensile strength.

Special thermits are also introduced into heavy steel ingots to prevent the tremendous waste from piping, and further into the molds of castings just inside the risers, by which iron which was on the point of getting plastic is revived.

The examples given above are only a few instances of the usefulness of aluminothermics.

The lecture was illustrated by numerous experiments, among which was the burning of a hole through a ¾-in. steel plate in about 10 seconds, welding this hole by thermit, and the welding of a full-sized girder rail.

Broken Stern Post.



Welded Stern Post.

Mold for Welding Stern Post.

UNDERGROUND AND SUBMARINE CONDUITS FOR ELECTRIC WIRES

By D. A. Harrington, Member of the Boston Society of Civil Engineers.

[Read before the Society, February 15, 1905.]

It is my privilege to speak to you this evening on a subject which, though probably more or less familiar to most of you, is a very modern branch of engineering.

If one could have looked beneath the pavements of our cities only twenty years ago, there would have been found among the network of water and gas pipes and sewers, only an occasional modest sample of electric conduit.

But during its short life this infant has been nurtured by many trained minds and fed with millions of dollars of capital, and under these inspiring influences it has grown and flourished to a remarkable degree.

We may now find the conduit for electric wires elbowing its way among its companions beneath the pavements in every part of our cities, and making great strides of ten, twenty and fifty miles from one city to another, so that to-day it claims a place in the front rank of distributing mediums in point of scope, utility and commercial importance.

About fifty years ago it was proposed to lay a line of underground wires from New York to Baltimore. The work was commenced, but was not successful, and a pole line was constructed instead.

Soon after, on one of the railroads in this state, a car was equipped with a plow projecting at one side, at the front end, to open up a furrow parallel with the tracks; a reel of wire was placed on the car with apparatus for feeding the wire into the furrow, and at the rear end of the car was fastened an implement for throwing the dirt into the furrow, covering the wire. Thus, while the train was in motion, the trench was dug, the wire laid and the trench refilled all at one process.

This would rather seem to put to shame our present method if the work had been permanent, but, unfortunately, this was not the case.

Practical underground conduits were first constructed in this country about twenty-five years ago, and since that time the growth has been steady and very rapid. All of our large

cities are now practically honeycombed with pipes for electric wires, and at the present time it would seem impossible to do business without them.

In Boston to-day there are about 1,900,000 ft. of conduit, made up of about 8,800,000 ft. of duct. In the ducts are about 10,300,000 ft. of cable, containing from 1 to 800 wires each, giving a total of about 500,000,000 ft., or 100,000 miles of wire.

There are about 6,000 manholes and 12,000 service connections from the conduit systems to buildings and poles.

There are *two* main divisions of conduit systems, the solid systems and the drawing-in systems.

A solid system is one in which the wires or conductors are laid in some insulating compound in pipes or boxes, the joints made and the work completed while the trenches are open. This system has been extensively used for electric light and power, and to some extent for telephone and telegraph purposes. It has especial advantages of flexibility in construction, as it can be laid with bends, curves and square corners as well as straight lines. The varying lines of the highways and byways can be easily followed and obstructions in the streets avoided, while at the same time it can be laid comparatively near the surface of the street. This system is especially adapted for local distribution.

The disadvantages of this system are, first, that in many cases the original economy of construction is curtailed by the excessive number of wires placed to provide for possible future necessities, and, second, that in case of the failure of any conductor on account of mechanical or electrical injury, the conduit must be uncovered and the insulation removed in order to make repairs, and in case of additional wires being required, practically the entire process of construction must be repeated in order to install such wires.

A drawing-in system is that in which manholes are built at convenient distances, trenches are opened between, and pipes are laid connecting one manhole with another; the trenches are then refilled, the surface of the ground restored, and at any convenient time the cables are drawn in and out of the ducts between the manholes and connected as desired.

The principal advantage and economy of this system is that only such cables as are needed are drawn in at first, and additions, changes and repairs can be made as required without disturbing the surface of the ground.

This is a very important advantage because of the liability

of defects developing in the conductors from various causes; because of the frequent calls from customers for different or additional service and because of the rapid improvement in manufacturing the conductors and operating the system; all of which conditions make it a distinct advantage and economy to be able to conveniently repair, change or install conductors at any time of the year.

Many different materials have been used in the construction of drawing-in systems, the most popular being wood, cast-iron, wrought iron, cement and clay.

Wood, when used in the construction of conduits, is generally treated for preservation by kyanizing, vulcanizing or creosoting; it has been used both in its natural state and as a pulp in the construction of single and multiple ducts. Multiple ducts were first used, but of late years the single duct is most used.

In making multiple duct wood conduits it has been customary to use 2-in. plank for the outside walls and inch boards for the interior partitions, these parts being framed and nailed together in 16 ft. lengths; the sections are placed in the trench to line and grade, and the joints are wrapped with tar paper smeared with pitch and secured by nailing on cleats of inch boards; the whole is then further strengthened and protected by spiking 2-in. planks on top, so laid as to break joints with the sections of conduit. This makes a very firm, strong conduit, but its rigidity is an objection to its use in congested city streets on account of the difficulty of making curves and bends to avoid obstructions.

Single wood ducts have been made by boring a 3-in. hole lengthwise through a stick of spruce $4\frac{1}{4}$ in. square; they are furnished in 8-ft. lengths with a few short lengths for convenience in use; each piece is fitted with tapered socket joints and the finished lengths are treated with creosote.

In building a conduit of this material the lengths are driven together in the trench in the number and grouping desired and a covering plank is laid on for protection.

A conduit of single wood ducts protected simply by a covering plank can probably be laid more rapidly and at less cost than one of any other material used, and it has been quite popular in suburban districts where a few ducts are needed and the development of business is not sufficiently advanced to enable the determination of the location and extent of permanent requirements.

Wood pulp has been used quite successfully in the manufacture of pipes for carrying wires, made up in lengths of about 6 ft., with smooth sleeve joints or screw couplings; it is claimed to be water- and acid-proof and an insulator electrically. The price charged for this pipe has been until lately so high when compared with other material as to practically prohibit its use in general underground conduit work, but it is now sold at a figure which compares quite favorably with other pipe and is being used quite extensively; the smaller sizes of pipe, from 1 to 2 in. diameter, have been quite generally used for carrying wires in the concrete floors and walls of power stations and other buildings.

A few years ago an underground system was designed in which the conduits and manholes were made of cast iron laid up in sections, with special fittings for making connections to buildings, poles and lamps. This system had many good points in design, but the lines on which it could be laid were too rigid for convenient street construction and the material was comparatively fragile. Conduits of this material were installed in two or three cities; it did not become popular, however, and has not been used to any extent during the past ten years.

Wrought-iron pipe of heavy and standard weight, and the lighter well casing and boiler tubing have been used to a very large extent and by men of all degrees as receptacles for underground electric wires; there have been special machines made for bending the pipe on the work and special couplings for connecting bent pipe; with these accessories a wrought-iron pipe can be made into a very serviceable duct for wires along a crooked path, and as such has been very popular with engineers and contractors when considering the problem of building a conduit over, under or around perplexing obstacles.

In the early days of conduit work, iron pipe was quite generally used even for the larger conduits, but of late years the comparatively high cost of the pipe with proper protection, and the fact that from an electrical standpoint an iron pipe is not a satisfactory receptacle for wires, have limited its use to small lines or connections to buildings, poles, etc.

Cement-lined pipe consists of a cylindrical jacket of sheet iron with a lining of cement and iron socket joints; it has been made in 8-ft. lengths, can be laid very rapidly and when properly covered with and separated by concrete, makes a very strong and satisfactory conduit. It has been used very extensively; the writer has supervised the laying of 2,000,000 ft. in one city

in a single season. While the cement-lined pipe is not as flexible for use in conduit building as wrought-iron pipe, a very satisfactory curve can be made by cutting the pipe into short lengths and making a slight bend at each joint, and the round shape gives it a distinct advantage over the square duct in that by properly manipulating the round pipe in the concrete matrix, the grouping of ducts and shape of the conduit can be changed without breaking the continuity of the ducts. This is a great convenience at times in avoiding obstacles.

Vitrified clay conduits are made in single and multiple ducts. The single duct consists of clay pipe $\frac{1}{2}$ to $\frac{3}{4}$ of an inch thick, with a 3-in. bore, and is made up in 18-in. lengths; it is made with socket joints or plain square ends.

In laying a conduit of this material, a concrete bed is prepared in the trench, and on this the sections of conduit are laid in the grouping desired, care being taken to have the sections in accurate line with each other and so arranged as to thoroughly break joints horizontally and vertically; each course of ducts is bedded in a thin layer of cement mortar.

The grouping of ducts is then covered on the sides and top with a layer of concrete. A covering of plank is generally laid on the top concrete to protect the conduit from mechanical injury.

Multiple-duct vitrified clay conduits are made, containing either 2 ducts, 3 ducts, 4, 6 or 9 ducts; the sides of the conduit and partitions are made from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. thick; the ducts are either square or round and from 2 in. to $4\frac{1}{2}$ in. inside measurements.

These multiple ducts are made in sections from 2 ft. to 6 ft. long, held in line by iron dowel pins, and are laid with or without a concrete envelope as the conditions require; in either case, however, the joints at least are wrapped with cloth, paper or burlap and covered with pitch or cement mortar. It is advisable to place a covering plank on this and all conduits laid in public streets.

Vitrified clay conduits in the single and multiple forms have been used more extensively during the past three or four years than those of any other material.

The principal feature in favor of this material is its cheapness, but it has good points in which it equals more expensive materials and excels cheaper kinds, with the result that it has become very popular among those who have been buying conduit materials in large quantities.

Some of the good mechanical points of the duct made of vitrified clay are that it has a smooth inside surface, is probably permanent, is an insulator, and, if properly laid, is reasonably water and gas tight.

The objections to it are, the lack of proper joints and the short length of the sections, which increases the number of poor joints; its weight also is a factor of considerable extra expense in freight, teaming and handling.

There have been several attempts made to manufacture a glass pipe for use in underground conduits, and some excellent samples have been produced, but it has not been put to any general practical use.

Of late years there has been a demand for large quantities of pipe or duct at a very cheap price, and the result has been the production of ducts which, while good considering the price, are still far short of perfection.

The cost of the pipe or duct is generally only 10 or 15 per cent. of the cost of the finished conduit, so that an increase or decrease of even 50 per cent. in the cost of the duct would mean only a change of 5 per cent. in the total cost of the conduit.

The fact that the duct is usually purchased in large quantities (a single order often being placed for all the duct for a season's work) gives an undue prominence to a small per foot saving, and while the resulting percentage of saving on the whole conduit is very small, the defect in the duct, which is the vital part of the conduit, is a defect in the same degree to the whole conduit.

In laying the ducts now generally furnished, we are dependent for good results on the skill, accuracy and faithfulness of the man who does the actual work of placing the ducts in position, and, as the ducts when laid are of necessity covered so as to be out of sight almost immediately, there is a liability that poorly matched pieces, or pieces that have slipped out of position on the fresh mortar, will be covered up; this has frequently happened in practice and has incurred an ultimate extra expense in operating the conduit far in excess of the extra cost of a duct of better design and construction.

In the interest of good conduits it is desirable and probable that there will be a popular demand for ducts so designed that they can be easily placed and maintained in correct position in relation to each other.

The laying out of a conduit system is somewhat similar to the laying out of a system for distributing gas or water.

The location of the central station and the area to be supplied having been determined, the nature and extent of the business throughout the district can be profitably investigated in considerable detail, and an estimate made of the probable growth of business in the different sections in a given time.

Having thus estimated the amount and character of the electrical service which will probably be required in each portion of the district, it can be successively determined, first, what wires and cables are necessary, and then the size and location of conduits required to contain such cables.

In each of the above estimates, and especially in the matter of conduits, it has been found by experience to be advisable to leavè a substantial margin for unforeseen contingencies.

Underground conduits may be used for the wires of electric railways, telegraph companies, telephone companies or electric light and power companies, and, while the same general style of conduit is adapted to the use of either, the requirements in details of distribution are quite different, and the nature of the service required must often be considered in locating the conduit and determining the number, location and size of manholes.

The layout of a distributing system for the feed wires of an electric railway is such as will provide a direct and convenient route for cables from the power station to certain fixed feed points on the line of the railway; no provision need be made for intermediate distribution and the manholes are required only to be built of such a size and placed at such intervals as to provide for the convenient and proper handling of the cables.

A distributing system for telegraph wires is required principally to provide for trunk lines in and out of the cities, but the occasional lines run to private offices and the wires for messenger calls make it necessary to provide for reaching all important buildings, and for this purpose the conduit should be so located as to be accessible at practically all points in the business district, and the manholes should be so located as to conveniently connect from them to the required buildings.

The underground distributing system for the wires of a telephone company must provide for trunk lines in various directions, and also for connecting to individual buildings in all parts of the district; the problem in this case is considerably simplified by the fact that because the service required is all of the same character and the amount of current used is so very small, many wires for all the service in a locality may be bunched

together in a small space and carried through or along the sides of buildings without danger to persons or property or detriment to the service.

In designing a conduit system to properly accommodate the wires used to distribute the current from an electric light and power station, the conditions to be considered are much more complicated than those mentioned above. The conduits should be such as will properly contain and protect cables carrying currents of from 200 to 20,000 volts, and the manholes so equipped as to provide means of protecting the cables of various voltages from each other, and of such size and shape as to allow for the safe and proper handling of the cables and space for installing such junction boxes, transformers, etc., as may be required.

The local distribution of electric light and power wires is a matter on which engineers, electricians and municipal and insurance officials have many opinions; it is a subject which should certainly be handled with care and intelligence.

In some cases the customers in the vicinity of the stations have been supplied by laying a solid system of tubes for low-tension currents from the stations through the main streets and connecting directly with the buildings to be served.

In other cases a combination of drawing-in system and solid system has been employed by sending low-tension current through cables in conduits from the station to certain determined points throughout the district and there connecting to solid tube lines which carry the current to individual buildings.

Another method is to send high-tension current from the station through cables in conduits to points in the immediate vicinity of the customers to be served, and there transform to a voltage suitable for the work, and distribute the weaker current into the buildings. The transformers may be placed in manholes or vaults or on poles or buildings.

The current is also sent out from the station at from 500 to 3,000 volts and used without transforming for power or lighting.

It is of great advantage to determine which of the above methods or what combination of them is to be used before laying out the conduit system, which can then be designed to suit the plan of distribution decided upon.

When an underground system is to be laid out, it is generally designed to take the place of an overhead distributing system, and in that case the plan is often to place only the main lines underground at first, to connect at convenient points to

pole lines or house tops and continue the local overhead distribution. This is somewhat of a saving at first, but in practice the combination has generally been only temporarily continued and eventually the thoroughly underground system with individual building connections has been usually adopted as tending to true economy and good service.

Having in mind the varied conditions as noted above that may arise, it is evident that in making the original design for a system of underground conduits for an electric light and power plant, due consideration should be given to the probability that there will be an ultimate demand for an entirely underground distributing system. This will often be a factor in choosing locations for conduits and manholes, and a reasonable extra expense is in some cases warranted in the original work in order to provide for probable future requirements.

A scheme which is often proposed and sometimes finds favor with managers and engineers who desire to do thorough work, is to construct either one or two conduits in each street, separate from the main line, to be used only for local distribution; from these smaller conduits connections are at once made to all buildings where service is or may at any future time be required.

This would seem to provide well for future business and preclude the necessity of any further excavation in the street, — two important features in its favor and which make it in a few special cases an ideal system. For use in the average city, however, this system seems to be more ideal than practicable.

The discrepancy between the possibilities which must be provided for in such a system and the use that is actually made of the facilities provided is so great that the cost figures out of all proportion to the probable benefit to be derived.

The method generally employed is to make connections to buildings from the main conduit line when practicable and to run spur lines into localities where business is reasonably assured and the main line is not accessible.

It is at times considered very desirable to construct a common conduit system for the wires of two or more companies, in the interest of economy and to avoid the inconvenience of constructing parallel lines in the same streets. If the work is laid out and constructed without proper consideration and care, there is great chance for trouble from such a combination, but if the use each company is to make of the system is intelligently considered in designing the conduit and locating the

manholes, and the proper extra care taken in construction because of the peculiar nature of the work, it is perfectly feasible to construct an underground conduit system which shall be satisfactory for the use of two or three companies.

The number, location and size of manholes to be built is governed by the requirements of the system and local conditions; it is possible to properly operate a conduit with stretches of 700 or 800 ft. between the manholes, but it is considered best to limit the distance to about 300 ft. where practicable, and manholes *may* be placed as often as is necessary to meet the local conditions.

Manholes should be located at the low points in the grade if practicable, as it is an advantage to have all parts of the conduit system drain to the manholes.

There must be a manhole at each point where two conduits intersect, and others are located at convenient points for making connections to buildings, etc.

The minimum practical size for a manhole is about 3.5 ft. × 4 ft. × 5 ft. deep, and should be limited to conduits of 4 ducts or less.

A manhole 5 ft. × 6 ft. × 7 ft. deep is considered satisfactory for a conduit of 12 to 15 ducts, and one 8 ft. square and 10 ft. deep will serve for 30 or 40 ducts.

The kind of service to be performed and the character of the current to be used should both be factors in determining the size of manholes, and when apparatus other than cable is to be installed in a manhole, its dimensions should be increased for that purpose so that the space for handling cables will not be reduced.

Manholes are made with walls of brick masonry or concrete; the tops are of stone slabs or brick masonry supported by steel beams, or of reinforced concrete, with iron frames and covers.

In the suburban districts where many manholes of the same size and shape are to be constructed, the use of concrete has become quite popular, but in the congested streets of the cities, on account of the peculiar shapes often required and general lack of similarity between manholes, nearly all have been built of brick masonry.

In designing the iron frame and cover, the circular shape has a distinct advantage over the square, in that the square cover may fall into the hole to the detriment of the cables, while with the round cover this is impossible.

Having, as above described, determined what cables and conduits are required in the different portions of the district for local service and trunk lines, the next step in the laying out of the system is to determine by the accumulative method, with proper allowances, the size of conduit required for each portion of the route to the station.

The investigation so far outlined will determine in what streets of the district conduits are to be built, but in choosing the route for the larger main line conduit from the station, it is often found that two or three streets are about equally suitable as regards directness of route, and in this case it is well in making a choice to consider the general surface conditions and the underground structures in the streets in question.

This brings us to the question of detailed street plans, regarding the necessity for which there is some difference of opinion.

There can be little doubt as to the advisability of providing plans containing all information obtainable in regard to streets where conduits are to be built in the congested portions of cities.

In the smaller cities and suburban districts some engineers of experience prefer to dispense with detailed plans and to be guided by advance investigation at the time of building the conduit.

This may be at times a wise policy, but on general principles it is safe to maintain that the money expended in plans intelligently made is well spent, and the information obtained, however meager, is well worth what it costs.

The preliminary plans of city streets may show gas and water pipes, sewers, pneumatic tubes, electric conduits, heating conduits, sidewalk lines and areas, subways, car tracks and cross-walks.

It is also well to note the grades of the street surface and of underground structures when possible.

These plans, in order to be reasonably reliable, should be made by or under the immediate supervision of one who is well informed in regard to the structures to be found underground and the details of their construction.

In some cities the location for the conduit in the street is designated by a city official, but usually the engineer in charge of the work submits a proposed location to be approved by municipal authorities.

The determining of this location is an important matter and one to which the engineer may well give careful considera-

tion, as an error of judgment in this detail is likely to be expensive and may lead to a permanent defect in the system.

The conduit should, when practicable, be laid to a straight line and grade; this is especially desirable where the ducts are to be well filled with cables, or long distances between manholes are required.

A curve of reasonable radius is not a serious objection where the length between manholes is short, but bends or sharp curves are objectionable at any point in the system and should be avoided.

In constructing the conduit of either of the materials mentioned, the quality of the work performed in the construction is really the important factor, as the best materials cannot give good results unless properly handled.

The fact should be constantly kept in mind that the work is to be immediately and permanently covered from view, and any defect in material or construction will remain a defect and become a part of the system.

When the conduit is to be built by contract, detailed specifications should be prepared and the work should be thoroughly inspected while in progress.

The questions of drainage and ventilation of the conduit system may well be considered together because the usual method of drainage by connecting the manholes with sewers makes a reason for ventilation, and the popular method of providing ventilation by perforating the manhole covers creates an additional demand for drainage.

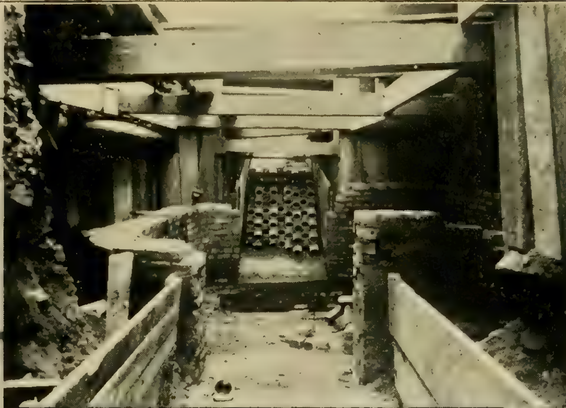
The opinions of engineers vary to a very wide degree in regard to the advisability and necessity of draining and ventilating manholes.

In one or two localities all manholes have been equipped with drains and a pipe run through each manhole to supply air under pressure; openings in the pipe in the manholes were so regulated as to produce a pressure of air in the manholes slightly in excess of the pressure of gas in the ground adjacent. This system is effective, but expensive and not generally warranted.

In some systems all manholes are supplied with drains and all covers perforated, with the idea that whatever gas or water comes in one way will go out the other.

A method of dealing with the matter which has been tried with success in several cities is to make all manholes reasonably tight, waterproofing when necessary, provide against gas by plastering the manhole walls thoroughly and closing all ducts

Conduit of 72 Single Ducts entering Manhole.



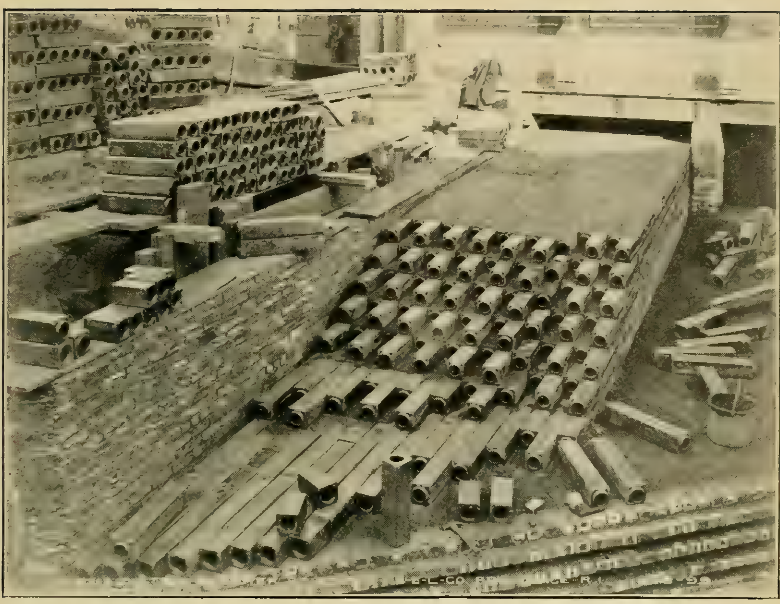
Vitrified Clay Conduit, 2 and 4 Duct Multiples.

Manhole and Different Groupings of Multiple Duct.

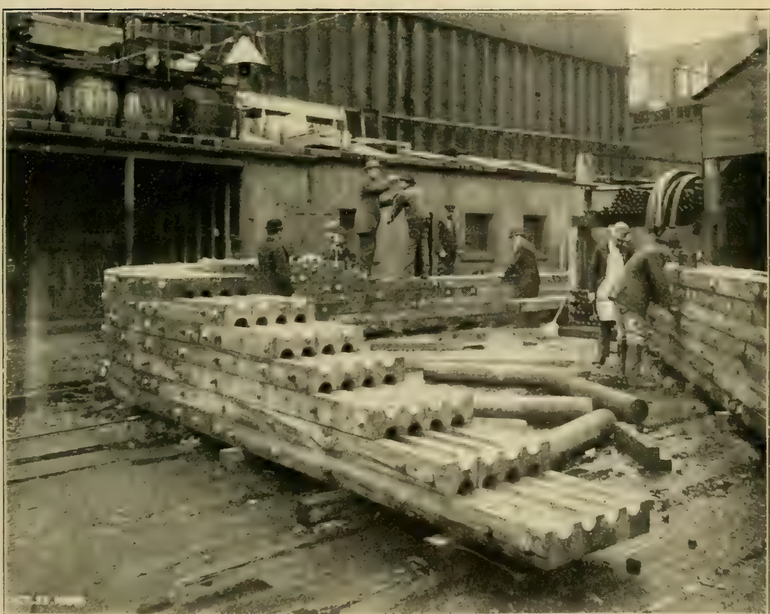
Conduit of 64 Single Ducts with Plain Ends.

WATERPROOFING FOR MANHOLE.

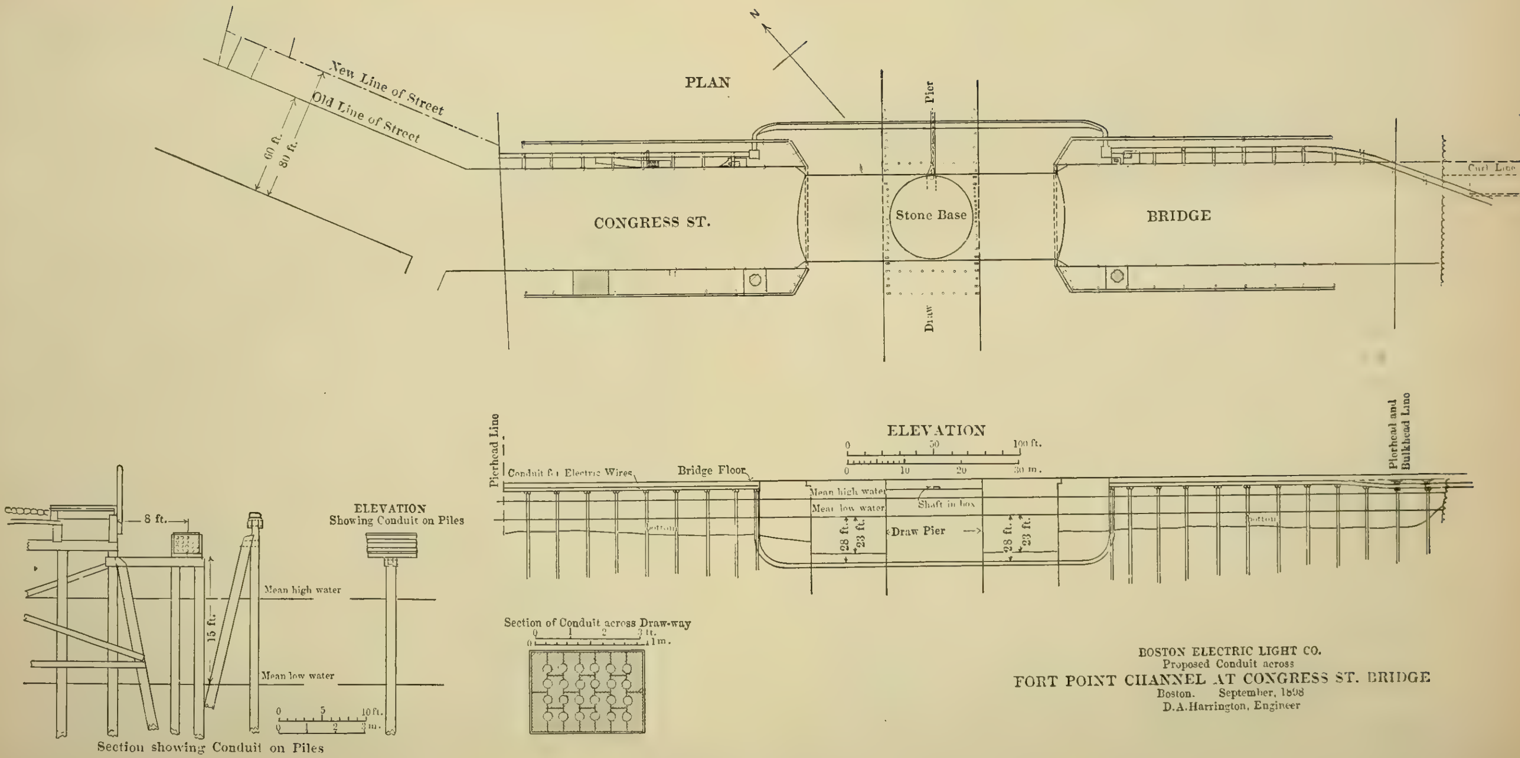
CONSTRUCTION OF MANHOLE INSIDE WATERPROOFING.



Half of Conduit of 244 Single Ducts with Socket Ends.



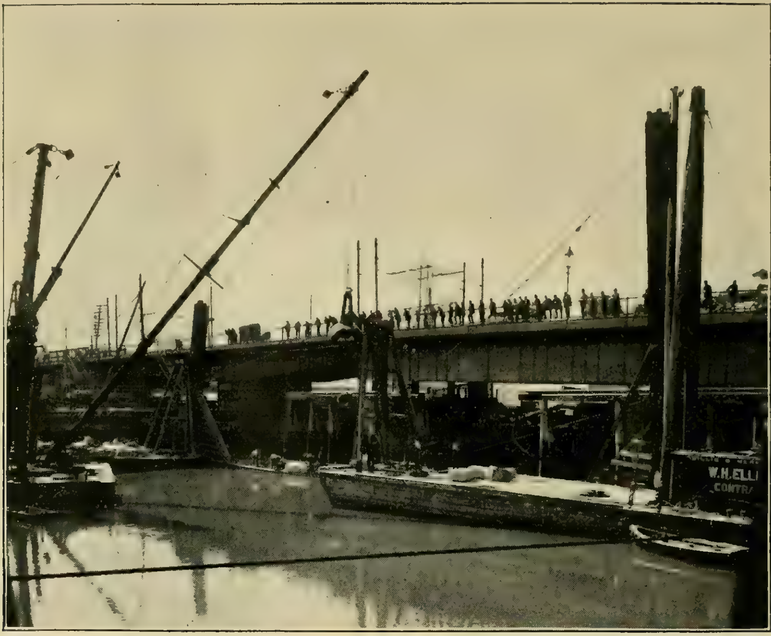
Building Submarine Conduit.



SUBMARINE CONDUIT.

Congress Street Submarine Conduit in Transit.

Dover Street Submarine Conduit, showing Bracing for Handling.



Loading Conduit with Stone for Sinking.

Lowering Conduit into Position at Dover Street Bridge.

at the manholes, and, by a tight inside cover, prevent the water from coming in from the street. In this way the manholes are practically isolated from the surrounding soil and from each other, and any leakage of water or gas will be so small to as give little trouble.

The closing up of the ducts between manholes prevents the spread of gas or water from one to another, and in case of gas especially this greatly facilitates locating the leak.

This method of sealing the manholes up from outside influences is quite an advantage over having gas and water and sometimes steam and sewage pass in and out of the system.

In passing to the subject of submarine conduits, it will be well to mention briefly the circumstances which led to the construction of those which will here be described and illustrated.

When the power station of the Boston Electric Light Company at Gilbert Place was to be discontinued and a site for a new station was selected at L Street in South Boston, it was found that in order to send the current by a reasonably direct route from the new station to the central part of the city, the cables would have to cross Fort Point Channel and the Reserved Channel near L Street.

It was of the utmost importance that the cables should be so placed that there would be no probability of their being disturbed or injured, as the failure of these cables would mean practically the shutting off of current from the main portion of the city.

To have laid submarine cables would have entailed a large expenditure for the purchase of a sufficient number of armored cables, the dredging of trenches across the channels, the placing of all cables required, and filling in the trenches to protect the cables from dragging anchors.

In case of additional cables being required at any time, the dredging and filling would have to be repeated, and in case of the failure of a cable, the process of replacing would be slow and expensive.

After thoroughly considering the problem, it was finally concluded to construct submarine conduits so as to practically continue the underground drawing-in system across under both channels.

Previous to this time a submarine conduit for telephone wires had been laid across the Harlem River near High Bridge in New York.

The conduit was composed of a number of wrought-iron

pipes with screw couplings, and protected on the outside by winding many layers of cloth saturated with a compound to preserve the pipe from action of water.

The pipes were bent to conform to the general contour of the river bottom, fastened together and the whole was covered with a jacket of creosoted wood.

A trench was dredged to a careful grade and the conduit was placed in the trench and covered.

In September, 1898, the first submarine conduit in Boston was laid for the New England Telephone and Telegraph Company under the channel of the Charles River at Warren Bridge.

This conduit contains seven wrought-iron pipes with screw couplings, each pipe having a protecting covering of several layers of asphalt and cheese cloth.

The pipes were assembled and secured in proper relative position each 2 or 3 ft. by being passed through wooden diaphragms 4 in. thick and 16 in. in diameter.

The whole was then enclosed in a shell of creosoted wood, 4 in. thick and 24 in. outside diameter, secured by iron straps.

The completed conduit was shaped like the letter U, with a length of about 48 ft. between uprights and having a total length of about 128 ft.

A trench was excavated into which the conduit was lowered, and the trench was refilled.

Both of these conduits described were intended to be water-tight.

In designing submarine conduits for the main lines of the Boston Electric Light Company, it was finally decided to depart from all known precedent and build the conduit entirely of untreated wood.

The timber used was green pine, excepting for a section 12 ft. long in each of the uprights, 6 ft. above and below the mud line, where oak timber was used to avoid the attack of insects.

The conduits were made up of seven vertical layers of timber, each 6 in. thick, with semi-circular grooves planed in the opposite sides of each layer, so spaced as to leave, when the timbers were assembled, twenty-four parallel holes $3\frac{1}{2}$ in. in diameter through the entire length of the conduit.

These and other details of construction are clearly shown in the illustrations.

The timbers were laid up with staggered joints and fastened together at frequent intervals by galvanized iron rods with nuts and washers and also by kiln-dried-pine dowel pins.

The rods were used as convenient in properly assembling the parts and the dowel pins were regarded as the permanent fastenings.

Both extended horizontally and vertically through the entire structure.

The conduits were built in sections with stepped joints on a wharf at Fort Point Channel; the sections were launched off the wharf and the joints between the sections were made up while they were floating in the water.

When the completed conduits had been tested, they were taken in charge by floating derricks and pile drivers and carefully towed to the positions where they were to be installed.

Trenches to receive the conduit having been previously dredged, the conduits were weighted with blocks of stone and carefully lowered into the trenches, the tops of the uprights were placed and secured in proper position and the trenches were refilled over the conduits to the levels of the bottom of the channels.

The conduit at the Reserved Channel was 75 ft. in horizontal length, with uprights 25 ft. in height.

The one at Fort Point Channel was obliged to pass under a double channel with a draw pier between, and was 200 ft. in horizontal length with uprights 40 ft. in height; the horizontal portion being laid 30 ft. below low-water mark.

The horizontal and vertical members were in each case connected by curves of 10 ft. inside radius.

The conduit at Fort Point Channel contained about 31,000 ft. of lumber.

These wooden submarine conduits as above described and illustrated have been in constant use under Fort Point Channel at Congress Street and Dover Street and under the Reserved Channel at L Street for the past six years; they have been very satisfactory in service and are apparently in perfect condition at the present time.

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THE USE OF CONCRETE IN SEWER CONSTRUCTION.

BY W. C. PARMLEY, MEMBER AMERICAN SOCIETY OF CIVIL ENGINEERS.

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THE use of concrete rests upon confidence in its integrity as a building material; and with increasing experience, the additional confidence gained leads to its use in ever widening fields. This process of expansion or adaptation was never more active than it is to-day, and in no field is this activity more noticeable than in sewer building.

Stone was naturally the first material to be used in building permanent sewers, but for many years, brick has so supplanted it, that the older material is all but obsolete. Now, again, the older and the inferior, in the march of progress, is giving way to a newer and better material, concrete.

But *why* this change? For centuries brick masonry has stood the test and has been almost the only material used, except for very small sizes. Probably four out of five engineers would answer that it is because it has been the most economical building material. Important as is the matter of cost, this thought is often held too prominently in the front, and while naturally it appeals most strongly to the layman, it ought not so to *control* the thought of the engineer. Let us see, then, what advantages other than cost are possessed by concrete, which if sufficiently important should determine the choice of material, whether there be a saving or not.

The generally rough surface of a brick wall is a great disadvantage for any conduit used to carry water. This is

especially pronounced in small sewers where the curvature is too great for a smooth, continuous surface to be produced by rectangular bricks. Concrete gives a much smoother surface and a greater carrying capacity.

Again, in wet trenches, concrete is superior to brick masonry, as water can be held back by depositing a dry concrete mixture in place, and an impervious wall obtained that is otherwise impossible.

A third advantage of concrete is that a more resisting surface can be produced than with any but the hardest vitrified bricks. Witness the abrasive resistance of the surface of a well-laid sidewalk. Few natural stones, other than granite, are comparable to it.

As brick sewers are usually built of concentric rowlock rings of bricks, under severe conditions these rings tend strongly to separate or split apart, and so far does this deformation sometimes proceed that a complete inversion of curvature at the upper part of the arch is produced. Another and similar defect is where the inner ring of bricks falls completely out of the arch. Many such cases can probably be found in any of our large cities. Concrete obviously avoids these difficulties.

Portland cement masonry is more permanent than ordinary brick masonry. Sewers of common brick, not over twenty-five years old, are frequently seen in an advanced stage of disintegration. The use of best vitrified shale bricks should produce a wall of good permanency, but no greater than one built out of the best Portland cement concrete. In the present state of the art, then, the chances of securing a permanent structure are, at least, rather more favorable to concrete than to brick work.

With concrete, therefore, a sewer can be built that is equal to or greater in permanency than one formed of bricks, and at the same time smoother, more water-tight, and less liable to damage and collapse through excessive loads, vibrations or unsuitable foundations. The advantage of concrete in comparative cost is even more marked.

First. Within recent years the price of bricks has increased about 50 per cent. while the cost of Portland cement has decreased at least 50 per cent. The market price of broken stone and sand, while governed almost entirely by local conditions, has remained more constant, with a downward tendency.

Second. From 75 to 80 per cent. of the weight of the entire masonry wall, that is the bricks, must be transported from the factory to the site of the work. A large cost, therefore, is usually

involved in freight or teaming charges. On the other hand, frequently only from 8 to 10 per cent. of the weight of concrete structures, that is, the cement, has to be transported long distances, and since the quantity required is only slightly more than that for brick masonry, the gain is still more apparent. Sand, broken stone or gravel are very commonly to be had near at hand. The unsuitability of common bricks for sewer purposes and the high price required to obtain the shale or vitrified brick necessary to produce a resisting surface and durable sewer operate to increase the cost of masonry structures.

Third. Only skilled bricklayers can lay the bricks for a sewer, and as the labor is skilled, the cost is proportionately high. While the general trend of wages has been upward, the increase in those of the bricklayers has been vastly out of proportion to those of the ordinary intelligent general workman and the common laborer. In the case of concrete, nearly all the work can be done by the common laborer, so that the cost is proportionately low.

Fourth. On account of the limited number of skilled bricklayers, they naturally form unions to control and increase the price of their labor. The contractor, for personal safety, must take into account the risk of strikes, in preparing his bid. In the case of concrete work, only a small amount of skilled labor is required, and such as there is can be quickly learned by the ordinary workman. The contractor, therefore, is much less liable to be affected by delays of labor difficulties. The effective progress of an entire gang of laborers on a brick sewer often is seriously interfered with or entirely stopped by the failure of a few bricklayers to report for duty and do their assigned work at the proper time. In concrete sewer construction, the failure of a few workmen results in no such delay and trouble, as other men can take their places and the work go on without serious interruption.

Fifth. A brick wall must be built of sufficient thickness to contain the line of pressure near the middle third of the ring in order to prevent cracking and serious deformation. This necessity results in working the materials at a very low efficiency. For example, masonry that is capable of sustaining safely from 1 000 to 2 000 lbs. pressure per sq. in. is worked at a pressure rarely exceeding 300 lb. per sq. in., as to increase the unit pressure would produce rupture in the portion of the arch subject to tension. In other fields, the engineer is not satisfied with efficiencies of only one-third or one-sixth of what can be

obtained. Why should he be in this case? It is the good fortune of the times that he is not thus circumscribed, for, while the thickness of a wall made of concrete alone should be substantially equal to that of a brick wall for the same purpose, the concrete has the advantage in that it can be reinforced with steel. With steel reinforced concrete, the mass of masonry may be cut down by 50 per cent., and the materials composing the structure be worked at predetermined and properly ascertained efficiencies.

Sixth. The fact that a required strength can be obtained with less than two-thirds the amount of concrete when reinforced, than can be used when it is not so reinforced, leads us one step farther. For certain structures, the concrete may be molded into blocks of suitable size and shape beforehand, and then set in the finished work. This leads to great economy in the use of centering and falsework generally, and even economizes on that required for brick masonry, because, with concrete blocks, the percentage of soft mortar in the joints can be reduced to 6 or 8 per cent., whereas in a brick sewer arch, it forms from 25 to 33 per cent. of the entire mass. Hence, not only lighter centering can be used for a reinforced concrete block sewer, but such as is used need not remain in position so long and can be used over oftener. For sewers of about 4 ft. diameter or less, blocks can be so made as to avoid all centering, both interior and exterior, such as is required for either a brick or monolithic concrete sewer, and this is obviously a very material gain over brick construction or monolithic concrete.

Seventh. The disadvantage experienced in monolithic concrete as compared with brick masonry, is that inside forms only are used. The concrete is therefore banked directly against the side of the trench. It thus becomes necessary to specify a minimum thickness of side wall, and as it is impossible to excavate a trench to an exact width, the contractor must figure on using more concrete than that called for by the plan, the exact amount being determined by his confidence in his own ability to excavate to the neat line required by the plan. With reinforced concrete blocks, this extra concrete can be very nearly or entirely avoided, and well tamped earth substituted instead. The further advantage is possessed by the fact that a reinforced block structure would be concrete of good quality clear to the very edges of the structure, and hence the full theoretical efficiency of the concrete can be depended upon, which cannot be done in case of concrete deposited against ordinary forms.

Eighth. A concrete sewer, especially when reinforced, requires less width of excavation than does a brick sewer. This results, first, from the thinner side wall required, and, second, from the necessity of digging the trench for a brick sewer wider than the sewer, in order to permit the proper laying of the bricks on the portion of the arch immediately above the springing line. A further result is that the brick arch is more liable to deform because backed up with filled material, instead of by the natural earth.

These, then, are some of the advantages which a concrete sewer possesses over one built of brick masonry, and whatever comparative disadvantages there may be in the monolithic sewer, they are more than overcome by the use of concrete blocks.

The greatest drawback at the present time to the construction of concrete sewers is the prevailing timidity of the contractor to bid upon them, owing to inexperience in concrete work, and especially in reinforced concrete construction. The remark is often made by the contractor that the construction seems to be all right, but he dare not bid upon it until he has learned more about it. Or, that he will visit places where reinforced concrete sewers are under construction, in order to prepare himself to bid on future work. We are thus in the distinctly educative period of the art, and it is not only the contractors, but the engineers, often, that need instruction before *they* will venture out of the time-honored and beaten pathways. But the educative process is proceeding rapidly, and each year more and more concrete sewers are built.

Turning now from general discussion, permit me to give some notes and observations of personal experience. Early in my engineering career, nearly twenty years ago, I was introduced to the use of Portland cement concrete on a large scale, in the lining of irrigation canals and tunnels in California. For such purposes, concrete was common at that time. Even then, it was the ordinary method of lining tunnels in both earth and rock where permanent lining was necessary. Yet up to the present time, it seems impossible to convince some of our Eastern contractors that any material other than brick masonry is suitable for a tunnel roof. By properly constructed and manipulated centering, there is no more suitable material for tunnel purposes, and its cost should be less than that of brick work.

In Cleveland, where probably more concrete sewer work of late years has been done than in any other American city, the first important use of concrete for this purpose was in the

foundation of the Walworth sewer. The entire foundation and lower part of the side wall was built of natural cement concrete. The work was begun in 1896, and was in process of construction continuously for about six years.

Where it occurs in large mass, and is not subject to great unit stress, natural cement concrete is not only reliable, but often more economical than Portland cement. During the progress of the work, I had comparative tests made on about 800 briquettes, covering a period of two years. These tests showed that a good quality of natural cement mortar made 1 : 2, at the age of six months or over, developed nearly as much and in some instances greater tensile strength than mortar made 1 : 3, using the same sand and a representative Portland cement. Comparative observations were made on the natural cement concrete side walls and the Portland cement concrete of the arch after the lapse of a year with similar results. As a rule, however, it is only in the lower part of the foundation, where the bearing surface is large with corresponding low unit pressure that natural cement concrete is available, for the upper portions of a sewer must carry the earth load before a natural cement concrete would gain sufficient strength. On account of its economy, natural cement concrete was used for the entire foundation and side wall of the main intercepting sewer. This sewer, however, was lined, as was also the Walworth sewer, with two rings of the hardest vitrified shale bricks laid in 1 : 2 Portland mortar in the bottom, and with one such ring at the sides. The interceptor of 13 ft. 6 in. diameter is of reinforced concrete, with a total thickness at the springing line of the arch of 15 in., including the lining ring of bricks. In spite of this rather bold use of natural cement concrete, no trouble was experienced with the side walls, even in trench 40 ft. deep with the weight of 25 ft. of wet clay and sand backfill. The bottom of the trench was in a wet, soft, blue clay that in places heaved so (in several instances 18 in. or more) as to necessitate the removal and entire rebuilding of the bottom and central portion of the invert. An extra foot or more of concrete in these places prevented further rise till the arch could be built and loaded. Under the enormous pressures, side walls were occasionally forced in slightly before the arch was built. This tendency was checked by setting braces across the top of the invert and letting them bear lightly against longitudinal planks to distribute the pressure while the mortar was hardening. It was remarkable, however, how rigid even a green natural cement concrete wall was against those pressures,

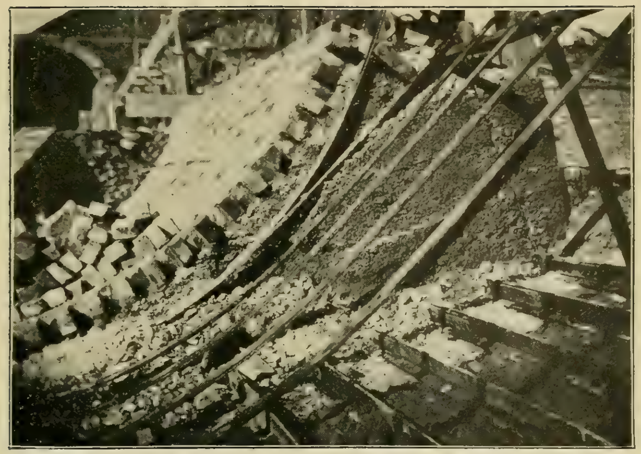
but this rigidity was no doubt due to the fact that the outer anchor bars of 2 in. by 0.5 in. steel, placed every 30 in., extended down 4 ft. below the top of the side wall and so resisted the overturning moment. Occasionally, in the deep trench, the width between the sheeting was pinched together, so that the total thickness at the side was only 12 in. or less. In these cases, the Portland cement concrete was usually carried down to about 3 ft. below the springing line.

In the matter of forms for invert work, the practice is not uniform among contractors. One of the first forms used in the Walworth sewer was like a piece of segmental arch centering inverted, and with the lagging nailed fast to the ribs. The trouble with this form is that it is difficult to tamp concrete under the bottom portion of the form, and hence a very rough surface is produced. Much better results were obtained by omitting the lagging boards on the bottom and at the sides till a point was reached where the inclination of the concrete surface was about 45°. The concrete for the bottom could then be worked down between the ribs, thorough tamping done, and a good surface obtained. The ribs serve as a guide, so that the workman produces the proper shape. From this point up to the vertical, good results can be secured with the ribs attached to the lagging. Some contractors found it more convenient to use ribs that were connected with each other by a skeleton framework only, and then to slip the lagging in, one piece at a time. For some of the sewers, in which the brick lining was not carried quite up to the spring line, a separate side form of skeleton ribs and loose lagging was set upon brace legs bearing on the bottom of the invert. This form carried the concrete from about 2 ft. below to about 2 ft. above the springing line. The arch ribs then became segmental and rested upon the middle braces. This method has the advantage of using ribs that are lighter and more easily handled than those that are semi-circular. For arch centering, it is necessary and convenient to use independent ribs and loose lagging, for the centers can then be carried forward piecemeal, the falsework upholding the green arch and re-erected at the advance end of the work. In these matters each contractor prefers to use his own ingenuity, and so long as the work is properly built, the engineer can well give him considerable latitude as to use of methods. One thing, however, the engineer must insist upon, — that all centering and falsework be as nearly rigid as possible. Even a slight settlement of the centers at the crown under the load of concrete and backfill will cause

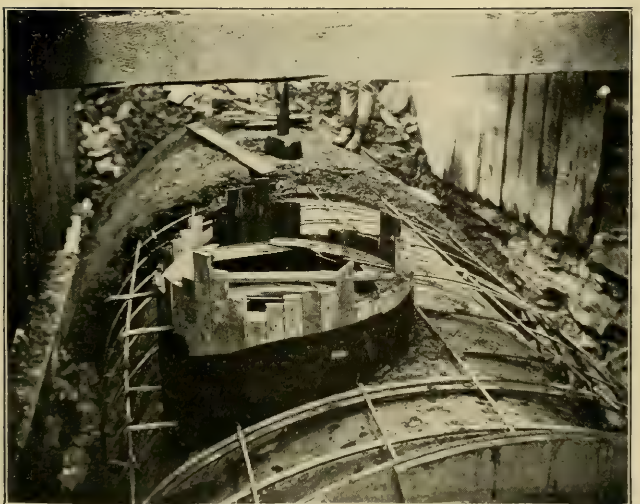
the arch to kick out at the quarters, and if the green concrete arch is not cracked at the crown, it will be crushed on the inside about half way between the crown and springing line. A reinforced arch is no more immune to this danger than is a plain concrete arch. However, with a few days of hardening, although the damage may be serious, the danger of actual collapse is less. A point to be guarded against, especially in reinforced construction, is any foolish act on the part of contractor or workman, due to his overconfidence in the strength of the structure because it contains embedded steel.

For wet foundations, the question of whether wooden grillage should be used or not is at times important. After a good deal of experience with the use of concrete in wet bottoms, my opinions have undergone a change. If brick masonry is to be laid where the bottom is both soft and wet, it is usually necessary to provide a plank foundation on which to begin the work. Practice suitable for brick masonry is often carried over to conditions where it is not only not necessary, but conducive to bad foundations in case of concrete. If quicksand is encountered, or material so soft that it rises, and there is a large quantity of water to be pumped, a plank platform should be used. In fairly hard but wet clay, or coarse sand or gravel, even though there may be considerable water, a more compact and solid foundation can be obtained by depositing the concrete directly on the bottom. It is very difficult to lay sleepers and cross planking so there will not be cavities underneath. Under the full weight of the structure, the planking will probably settle till all cavities are filled. If the grillage had been omitted, the concrete would have conformed to the irregularities of the bottom and prevented settlement. In case it is impossible to get rid of the water, use a dry concrete mixture, deposit and tamp it in as large mass as possible without much spreading. If it does not come in contact with flowing water, most of the cement will harden in place. Even if some of the cement is washed away from the very bottom layers of concrete forming the transition between the foundation and the soft earth supporting it, no fear need be felt, for even a good layer of broken stone or gravel would transfer the pressure safely, if there were no cementing material.

Concrete will flush up to the forms and produce a better surface, and the voids in the stone will be much better filled if it is so wet as to require but little tamping; moreover, there is less danger of obtaining a weak, porous wall should a workman

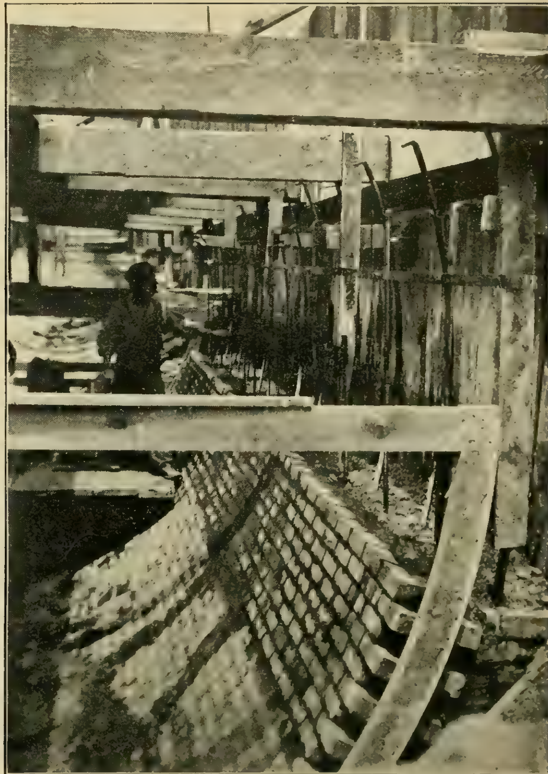


Sewer over the Siphon at Nine Mile Creek.
13 ft. 6 in. Diameter.

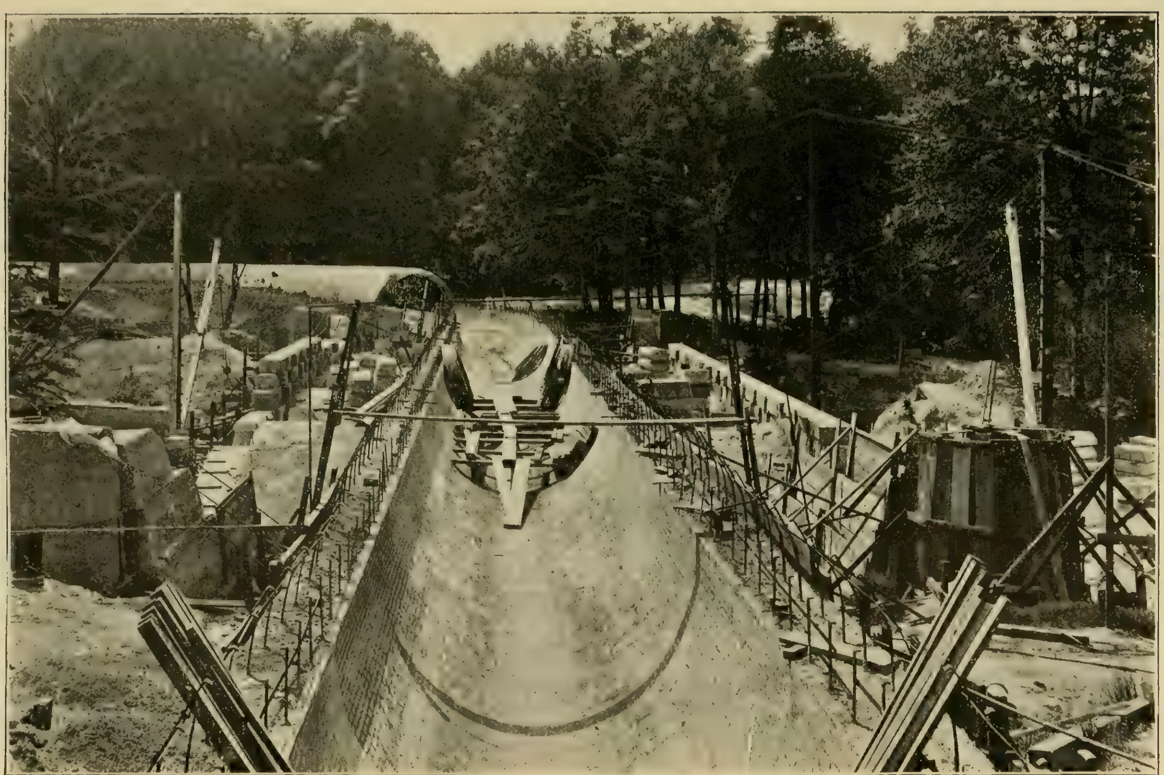


8 ft. Sewer and Manhole.

Anchor Bars, 13 ft. 6 in. Sewer,

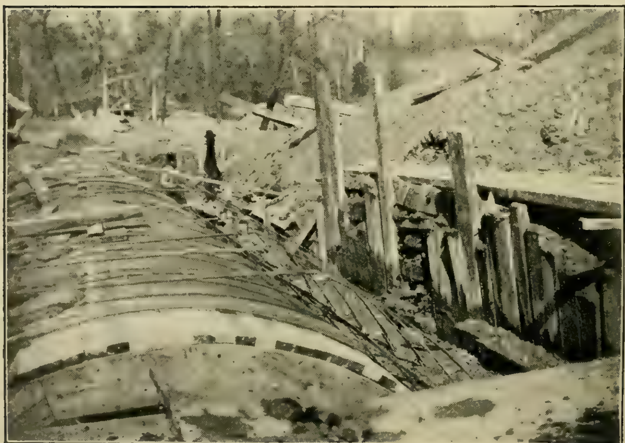


Method of Laying Brick Lining and Concrete Backing at Same Time,



Cleveland Intercepting Sewer across Doan Valley. (Diam. 12 ft. 9 in.)

Cast-Iron Mold for 24-inch Diameter Block Sewer, Reinforced Concrete.



12 ft. 9 in. Arch.

neglect thorough tamping, than there is where only a moist mixture is used. It is also to the contractor's interest to use wet concrete, for much less labor is required in mixing and placing it. Small broken stone or gravel is preferable in concrete for sewers. The walls being comparatively thin, unless there be a considerable excess of mortar, if coarse stones are used, the concrete will be honey-combed with voids. The stones should be well graded in size from large to fine, but the largest fragments should not exceed 1.5 in. in greatest dimension. It is not always possible to get the range and size of stones desired, and if both coarse and fine material are on the work, the coarser should be used in the bottom of the foundations and the finer stone reserved for the side walls and the arch.

In the selection of sand, a few years ago, it seemed to be the opinion of a majority of the Cleveland engineers that lake sand would give stronger result than bank sand, but laboratory results have contradicted this theory, and fairly clean bank sand is now generally preferred. Experiments in recent years have shown that a small percentage of clay in the sand is not harmful, and a better graduation of size between the coarse and fine grades can be obtained in bank sand, than there can be in that which comes from the lake.

Reinforced concrete has been very largely used during the last three years in the Cleveland sewers. About 3.5 miles of main intercepting sewer, 13.5 ft., and with a short section of 12 ft. 9 in. diameter; and upwards of four miles of other sewers ranging from about 5 ft. to 12 ft. diameter, have been under construction, and most of them are now completed. As the intercepting sewers were recently described,* only some points of detail in regard to the concrete work upon them will be mentioned

The question of cost of labor on the different parts of such work is of value, and while no complete data are at hand, a few observations may be given. Some of the contractors preferred to use hand mixed concrete, while others used concrete mixers. The results recorded were upon hand mixed concrete. The sewer gangs soon fell into a plan of division of labor, so that, except in case of accident or special contingency, the work went on quite regularly day by day. The common labor was largely Italian and the more skilled labor, American. The steel skeleton consisted of 2-in. by 0.5 in. bars 15-in. centers with a few longitudinal bars of 1.5 in. by 0.25 in. Two rows of anchor bars were set in the side walls, and the top bars were attached by means of

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bolts. The metal was all delivered from the mill accurately shaped, so that no bending was done in the field. The weight of metal per lineal foot of the 13.5 ft. sewer was about 93 lb. The concrete arch was 12 in. thick at the crown, and 15 in. thick at the spring line, as before mentioned. The time upon which estimates are based was reported by an inspector always on the work. The first observation covered two days' work, under average conditions, the workmen and contractor not knowing that notes were being taken. The figures, however, are for one day's work.

Labor placing anchor bars:

1 man,	$3.50 per day
1 man,	1.75 per day
4 hr. carrying steel at 20 cents,	.80
	$6.05

The anchor bars were placed for 40 lin. ft. of sewer, or about 1 504 lb. of metal at a cost of 0.4 of a cent per lb.

The concreting gang for the sides consisted of

5 men wheeling and mixing at $1.75,	$8.75
1 man tamping,	1.75
⅔ time man lowering brick and concrete at $2.25	1.50
1 man carrying concrete,	1.75
	$13.75

This gang built the side wall for 40 ft. of sewer daily, or 13 cu. yd. Cost of labor per cu. yd. was, therefore, $1.06. The concrete was tamped behind the brick lining as the latter was built up by the mason.

Cost of single ring brick lining at sides:

2 masons at 70 cents per hr.,	$11.20
1 man mixing mortar,	2.25
⅓ time man lowering at $2.25,	.75
3 men wheeling sand, filling buckets and dumping,	5.25
Total labor for 40 lin. ft. of sewer,	$19.45
Quantity of brick masonry laid,	6.38 cu. yd.
Labor per cu. yd.,	$3.05

An account was kept of labor performed on 85 lin. ft. of arch work, or $14\frac{1}{6}$ ft. daily. The force was as follows:

1 man putting mortar lining on centering,	$1.75
2 men mixing mortar, screening and wheeling sand,	3.50
1 man tamping concrete,	1.75
8 men on mixing board at $1.75,	14.00
	$21.00
No. cu. yd. placed daily,	25.64
Labor per cu. yd.,	$0.82

Placing centering and arch bars:

Men on centering and steel work:

2 men at $1.75,	$3.50
1 man at $3.50,	3.50
	$7.00

Cost, for $14\frac{1}{6}$ ft. daily, $0.49 per lin. ft.

As nearly as could be judged, about two-thirds of the labor was used in erecting the centering and one-third in putting the steel in place. The amount of steel placed daily was 785 lb. at a cost, therefore, of 0.3 of a cent per lb., and the cost of erecting and moving centers, $0.33 per lin. ft. of arch.

Another record of 39.27 ft. on a curve, gave for the cost of the brick work at sides the same result as above, but the inspector's record of men working on concrete backing at sides showed a less cost, as follows:

4 men mixing at $1.75,	$7.00
$\frac{2}{3}$ time man lowering at $2.25,	1.50
1 man in bottom,	1.75
	$10.25

They placed 12.7 cu. yd. at a cost of $0.81 per cu. yd.

This figure probably more nearly represents the average cost than the $1.06 reported in the first instance.

The cost of placing the anchor bars on straight sewer, representing average progress, at another time, was found to be:

1 man,	$3.50
1 man,	1.75
	$5.25

They placed the steel for 44 ft. of sewer or 1 650 lb. at a cost of 0.32 of a cent per lb.

Further notes for 6 days' work, when it seemed to represent as nearly as possible the general average for the whole were:

Labor on arch concrete:

Daily progress was $13\frac{3}{8}$ ft.

The force employed was:

7 men making concrete at $1.75,	$12.25
1 man plastering the center,	1.75
1 man mixing mortar,	2.00
1 man tamping,	1.75
	$17.75

On straight arch work they placed 24.1 cu. yd. daily at a cost of $0.74 per cu. yd. In three days' work on a curve, the same gang placed 26.37 cu. yd. daily at a cost of $0.675 per cu. yd.

On centering and steel for arch, three men kept up with the regular progress of the arch-concreting gang. The cost, therefore, is:

1 man,	$3.50
2 men at $1.75,	3.50
	$7.00

They averaged 13 ft. daily, or at a total cost of about $0.54 per lin. ft. of sewer.

Two-thirds of this labor was on the centering or $0.36 per lin. ft. of arch; $0.18 per lin. ft. placed the steel ready for embedding, or about 55.5 lb. per ft. of arch, at a cost of 0.32 of a cent per lb.

For the double ring brick lining at the bottom, the regular daily rate of progress was 28 ft. or 11.15 cu. yd. with:

2 bricklayers,	$11.20
5 men at $1.75,	8.75
1 man at $2.25,	2.25
	$22.20

or at a cost of $1.98 per cu. yd. This is given only because it is of interest in connection with the cost of the concrete.

Other observations on cost of placing steel skeleton and concrete did not vary materially from the figures given. It will be observed that no charge for superintendence or anything

for the general expenses is included in the estimates of cost. These charges were, of course, impossible to obtain. On another contract with machine mixing, as high as 36 lin. ft. of 13 ft. 6 in. arch were built in a day, but no data as to cost were taken, though it was evidently less than for the work with hand-mixed concrete.

Contractors sometimes object to bidding low on small concerte sewers, especially when reinforced, the objection being that the trench is too narrow for convenient working, that owing to the thin walls, the cost is proportionately high for each unit of volume, and that there is greater danger of the carelessness of workmen, causing trouble for the contractor. These troubles are serious only on sizes less than about 4 ft. diameter. But with reinforced sewers built of concrete blocks, suitably designed and manufactured beforehand, all these objections are avoided. The material for the blocks should be well graded, with the largest fragments not more than .75 in. in size, and with a considerable surplus of the mortar constituent, in order to make dense concrete. The proportions of 1 : 3 : 4½ will give good results, and a very superior quality is obtained with a 1 : 2 : 3 mixture. It is desirable, furthermore, to coat the inner surfaces with a paint of neat cement, applied with a brush, best applied before the blocks have acquired any considerable hardness. The reinforcing steel should be set in a thin mixture of 1 : 2 Portland cement, or, for special cases, a 1 : 1 mortar. As no centering whatever is required for the smaller sizes, they can be conveniently built in a narrow trench; there is no danger of spots of poor concrete making a defective sewer wall, and the sewer can be backed up with well tamped earth, which cannot usually be done in monolithic construction. The ease and accuracy with which the invert blocks can be laid in a wet trench, and the work generally protected against the damaging effect of water during construction, besides many other advantages, appeal strongly both to the contractor and the engineer.

I have no hesitation in saying that at some future date, reinforced concrete will be the material used above all others for sewer building. How soon that time shall come will depend upon ourselves as engineers.

DISCUSSION.

Question. — I would like to ask a little more in detail how the joints for concrete block sewers are made.

Answer. — The joints of the block sewer can be either radial, or they can be made with a symmetrical reverse curve.

Ques. — I would like to ask about the method of putting them together.

Ans. — We will assume that a foot is the standard length for a block, — I mean a foot lengthwise of the sewer, — and all the blocks are the same length in that direction. I am speaking now with reference to a small sewer where each of the four blocks makes the quadrant of the circle. The blocks for the lower quadrant would be like a concrete gutter in the bottom of a ditch, and the conditions would be such there that you could lay a very smooth invert, because the workmen can always see what they are doing, and the inspector on the top of the bank can see; whereas, if the joints are back inside of a pipe you cannot tell whether he is laying his pipes concentric with each other, or laying them so they will sag. When the side blocks are set, they should be set so as to break joints with the bottom blocks; that gives good foundation construction. The joints of the side and arch blocks do not break; they form a ring, and the inner edge of each block projects forward and butts against the square end of the block next ahead of it. That leaves a groove where the steel rods are grouted in, the rabbeted end of the block always facing the workman. It is thus in a position where he can do good work, and where he can easily place the steel rod.

Ques. (by Mr. Johnson). — Do you provide any longitudinal reinforcement?

Ans. — The longitudinal reinforcement in a four-block sewer is placed in the upper joints, at the upper quarters, and the most convenient shape is the thin flat bar, a little longer than the block, so that the bars will lap on themselves.

Ques. — What size do you make your block sewers?

Ans. — From about 20 in. up to 4 or 5 ft. diameter. For larger sizes it is cheaper to use monolithic concrete.

Ques. — Does the iron go through the bottom of the invert?

Ans. — Only where the sewer is to withstand internal pressure, or where it does not have any abutment support. There is a photograph (not reproduced) showing it standing as a ring with a large pile of building blocks on the top. In this case the steel has to pass clear round, the bottom steel being molded in the block and so as to be attached at the side to the steel passing over the top.

Ques. — You do not carry the longitudinal re-enforcement below the springing line?

Ans. — I do not think it necessary where the blocks break joints; it could be done if necessary just the same as at the top joints. In case the sewer is not supported continuously, it would, of course, be necessary to re-enforce it longitudinally. I am assuming a sewer in an ordinary ditch.

Ques. — In making junctions of sewers, would you make those junctions in concrete, or would you re-enforce them with brick?

Ans. — I would use hard vitrified slants.

Ques. — I referred to larger sizes, the junction of main sewers, particularly where there are large manholes.

Ans. — In that case you would set up short centres, and bring the blocks up as nearly as possible, and then with stone hammer do some trimming and fill in with mortar or concrete.

Ques. — By plastering inside?

Ans. — By having inside centering, and filling in from the outside. You can make a much smoother job if you cover the inside with paraffine building paper, because the paper will peel off and leave a very smooth surface.

Ques. — Have you ever tried the zinc form?

Ans. — I have never used the metal covering, but I have used a great deal of paper lining with great success, and it is exceedingly cheap.

Ques. — To what extent do you excavate, to the bottom line?

Ans. — The treatment is exactly the same as for a brick sewer. As the sides are set they are backed up with gravel or whatever dirt you have, the same as you would back up a ring of brickwork.

Ques. — You would not get the same uniformity of support as in monolithic construction, would you?

Ans. — Not quite, because in monolithic construction the concrete is built against the earth. If you were in a position where that were necessary, a thin concrete mixture could be poured in behind the blocks as the work progresses so as to give the same result.

Ques. — You frequently encounter materials you cannot shape, do you not?

Ans. — Certainly; in that instance natural cement concrete can be used as a filling at the bottom, or even gravel, in ordinary cases, would be sufficient.

Ques. — I see a photograph of a 13 ft. 6-in. sewer; what was the thickness?

ANS. — It was supposed to be 12 in. at the crown and 15 in. at the springing line. There are arches standing in perfect condition which are 12 in. at the crown and 9 in. at the springing line in a ditch 20 ft. deep.

QUES. — How thick would you make the same thing in brick?

ANS. — In the severer conditions I would not make it less than 18 in. thick at the crown and 30 in. at the springing line.

QUES.—Then the thickness of your arch with re-enforced concrete would be about one-third what you would put in of brick?

ANS. — No; where it was less than 15 in. at the springing line, it was caused by the side of the ditch pinching in, and the side pressures were such that it was physically impossible, with reasonable cost, to put it back, and there we substituted Portland cement for natural cement and let it go, and we haven't had any traces of weakness.

QUES. (by MR. DORR). — In your block concrete construction I understand the steel bars run down below the springing line.

ANS. — Yes.

QUES. — And you grout those in?

ANS. — You grout them in with thin Portland mortar.

QUES. — How do you confine the mortar when you get to the end of the sewer?

ANS. — It is confined by the earth backing. If the contractor does not tamp and keep the dirt close up against the block when he grouts it, some of the grout runs out behind, and so it takes more grout to fill the joints. It is for the contractor's interest to do the work well.

QUES. — You don't have to use any shell on the outside?

ANS. — A piece of metal could be placed behind the joint and then withdrawn, to prevent danger of dirt getting into the groove, or the blocks can be made so as to form a closed groove, which will prevent leakage.

QUES. (by MR. BRYANT). — What is the relative difference in cost of a 24-in. block sewer and a brick sewer?

ANS. — About one-half to two-thirds the cost of a brick sewer.

QUES. (by MR. DORR). — Where you put in branches, you would leave out the block?

ANS. — Simply leave out a half block, set your slant at a proper angle or elevation, and bank it in with monolithic concrete, or mortar.

QUES. (by MR. BREWER). — Are all the blocks molded in an iron mold?

ANS. — Yes.

QUES. — The idea occurred to me that it might take a good many molds to keep a big job going.

ANS. — No; the block is taken out of the mold immediately. The concrete can be put in the mold so soft that it will quake, but it is better to have it as wet as it can be without quaking.

QUES. (by MR. DORR). — These molds are made to take apart?

ANS. — They do not take apart; they are hinged. If you will observe the photograph you will see that they are hinged at one end and then locked. They open up like the blades of shears, and the blocks are left standing on a bottom board.

QUES. — You generally mold them at the work?

ANS. — That would depend upon the economic conditions, but get as near the work as you can.

QUES. (by MR. BLODGETT). — I noticed in one of these photographs a large concrete sewer with a brick lining. What was the idea of putting in a brick lining?

ANS. — That is very largely a concession to conservatism.

QUES. — I understand that you do not advocate the brick lining?

ANS. — It depends on whether you have good men to do concrete work; if you have, I would not use the bricks. But if you strike a place where you can get good brickwork and not skilled concrete men, you can get a better sewer by putting in a brick lining, that is, if you have good shale brick, but I would take my chances with a concrete sewer sooner than I would with brick, other than vitrified brick.

QUES. (by MR. SMITH). — There is one question I would like to ask about this concrete-steel construction. There is but a very slight change in temperature in sewage, but in water, or in water supplies, there is quite a marked change of temperature. Now, do you think that a concrete structure, for carrying a water supply, for instance, an intake or force main, would contract enough to produce transverse cracks?

ANS. — The coefficient of expansion of the concrete and steel are almost identical, so there ought not to be difficulty.

QUES. — I am not talking about the sliding motion of concrete on steel. I am talking about a continuous structure, say two or three miles long. All I have read about have cracked across the structure.

Ans. — Where the structure is well embedded in the ground there ought not to be difficulty in that way. In the case of iron pipes, no provision need be made if the pipe is well embedded in the ground, but if it is carried in the air, on trestle work, then expansion joints must be used. I have seen a movement of 4 or 5 in. in iron pipes that are carried in that way.

Ques. — The construction of concrete conduits, both in France and in this country, has developed transverse cracks at regular intervals; and my question was if your longitudinal re-enforcement was going to stop that.

Ans. — It might not on long ranges without the use of expansion joints.

Ques. (by Mr. Bryant). — Did you ever see any pipes coated with cement?

Ans. — I think I have not, but I have tried to protect the upper ends of anchor bars of the Cleveland sewer inverts where they were exposed to the weather all through the winter. I tried painting them with cement, and found that two heavy coats of neat cement would not last them more than through the winter without coming off.

Ques. — Wouldn't the moisture affect it?

Ans. — In a month's time the cement had begun to peel off by rusting underneath.

Ques. — Did you try white lead?

Ans. — No; simply painted them with cement, and in the spring scraped off the worst of it.

Ques. (by Mr. Parker). — I would like to ask Mr. Parmley if he has observed the influx of surface water into sewers where there would be a head of 3 or 4 ft. of water.

Ans. — That is one of the objections to a monolithic sewer, because, usually, when the structure is built the contractor's pump is moved ahead and the ditch, back where the sewer is completed, becomes subject to water pressure. In that case before the concrete has had a chance to harden very much the water comes against it and will sometimes force itself through the concrete in the form of small streams.

Ques. — I assume there was no underdrain.

Ans. — There was no underdrain. Where trenching machine is used, a great deal of water is carried back by the buckets, and dumped on the crown of the arch, and in that case the water will almost invariably force its way through the arch.

Ques. — I assume that the condition is such that you are not obliged to have underdrains.

ANS. — That is a matter of convenience. The trouble of underdrains clogging up has deterred the contractors from using them.

QUES. — I think you spoke of applying an outer coating to the forms, — am I right about that?

ANS. — That is true of the Cleveland sewers, although it is not in other cities where sewers have been built. In Cleveland practice the centers were covered with paraffine-treated building paper of medium weight, and then a layer of Portland cement mortar was kept against the paper in addition to the concrete. The concrete came on immediately, so it bedded into the soft mortar. It is to prevent the possibility of stones going through. In other cases the paper lining, immediately before the concrete is deposited against it, has been thoroughly drenched by water and the concrete put on fairly soft. The inside of the sewer is practically the same as when special mortar lining is provided.

QUES. (by MR. SMITH). — The paper being on there rather prevents what we call shovel tamping, does it not?

ANS. — To a certain extent. In such a case you would want to use soft concrete, and you would get better work anyhow.

QUES. — Even with soft concrete, isn't it rather essential that there should be this shovel tamping?

ANS. — I think not.

QUES. — Have you made any experiment as to the shrinkage of that wet concrete?

ANS. — We have only observed actual work constructed.

QUES. — You haven't made careful measurements, then?

ANS. — No.

QUES. — Did you have any instruments to observe the deformation of that 42-in. pipe under that heavy load?

ANS. — It was built upon a plank platform, that is, it was the most convenient place to locate it. As a weight was applied to the section, of course the platform might sink somewhat as a whole, so the use of an ordinary level was precluded. Chalk marks were made at a point at the crown and at the bottom, at the front and at the back, and then horizontal points at the center, front and back. I then took a piece of wood an inch square, with a screw in one end to make a steel bearing. At the other end, by means of fine wire nails as guides to hold an ordinary folding rule so it could be slid back and forth, and with a fine line drawn on the wooden rod, the rule was slid out until

it came in contact with the chalk mark. In that way I could very easily observe sixty-fourths of an inch. There wasn't that much deflection, and there were no hair cracks produced by the load.

QUES. (by MR. LARNED). — Can you reduce to the form of percentage the quantity of water you used in what you term wet concrete?

ANS. — It would be pretty hard to do it.

QUES. — Did you have any guide to go by, or did you judge by appearance?

ANS. — I judged by appearance. One or two per cent. would show in appearance.

QUES. — Would you expect to tell one per cent. by manipulation?

ANS. — I think possibly one could, that is, if the materials were exactly the same, but the materials vary and the contractor or workmen become expert and judge by picking up a handful of the mixture.

QUES. — You speak of very wet concrete as being one that will not quake?

ANS. — I meant very wet in monolithic work is concrete softer than the quaking point.

QUES. — One that practically pours?

ANS. — Nearly pours. Some of the best sewer work I have seen was built with concrete which was so soft that it would flow.

QUES. — Then your invert construction was made with perhaps a drier mixture?

ANS. — It was a drier mixture, although it was one that quaked.

QUES. (by MR. SMITH). — Then there must be some reason for making your concrete that you are to mold in blocks a little drier.

ANS. — It is under conditions where you can do better tamping than in monolithic work. When you put concrete down in a ditch, it is removed from the close observation of the inspector, and it is almost impossible to get workmen to do as good tamping as if it were on the surface of the ground where it could be inspected. With wet concrete this will not cause serious damage, but with dry concrete it will. On the other hand, in the case of molded blocks, it becomes more nearly analogous to laboratory experiments, where laboratory beams made with a dry concrete mixture give better results

usually than those of wet concrete. In a well-tamped block with the concrete so wet as to almost quake, therefore, we have about the same conditions that are obtained in the best laboratory work; that is, the conditions that give the greatest strength.

Ques. — Can you give us the percentage of water in that case in which the concrete develops the greatest strength, approximately?

Ans. — Only in this way: The cement and the sand are mixed first and then the water is added. Now, a certain amount of water goes in with the stones, but the water including that with the stones and sand would not be over about 8 to 10 per cent.; it would be pretty near the same consistency used in the laboratory for making sand briquettes.

Ques. (by Mr. Eddy). — You mix the mortar dry?

Ans. — Yes, rather dry.

Ques. — And put wet stone into the mortar and turn it over?

Ans. — Yes, and then the mortar clings to the stones.

Ques. (by Mr. Smith). — When you are making briquettes to test tensile strength, the less water you use, providing you use sufficient for crystallization of the cement, the stronger the briquette will be, well tamped. Now, does the same hold true with concrete?

Ans. — I don't know that I would agree with your first statement. There are certain limits between which you get the best results, and the more water you use and yet have the concrete so it will stand hard tamping, the stronger will be the result; but if you have the concrete so wet that it refuses to be tamped, then you will not get so strong a result. Where concrete is deposited in a large mass, wet concrete will give greater density, because the cement will flow through and fill the voids better.

Ques. (by Mr. Larned). — I would like to ask you if, before the setting time of the Portland cement with this wet mixture, you have noticed a tendency of a settlement of the aggregate?

Ans. — I never have. The arch must be carried absolutely on the falsework.

Ques. — You misunderstand my question. I meant a separation of the material. As I say, if you carry up 4 or 5 ft. of side wall in a short space of time, before the Portland cement has taken an initial set, have you ever noticed a tendency of the stone and sand to separate?

Ans. — You might if you had a large surplus of water on the top, but none usually that would affect the concrete as a whole.

Ques. — I am led to ask that question because I have somewhat decided views on the subject myself. While in New York I visited the East River tunnel and saw the construction of the steel lining and subsequent grouting. The men made experiments with grout mixtures of 1 to 2, and 1 to 3, with ordinary sand and also stone dust. They found it was impossible to put in that construction with a 1 to 3 mixture, and they reduced it to a 1 to 2 and afterwards 1 to 1½, and finally used stone dust. They found before the grout set that there was a separation between the two, owing to a difference in specific gravity.

Ans. — I catch your point. That is, a difference in the specific gravity between cement and sand.

Ques. — Yes.

Ans. — That has no reference to ordinary concrete mixture.

Ques. — No; but I see no reason why it should not hold good.

Ans. — Any person familiar with making brick mortar or any kind of mortar, knows that what a mason calls a dead sand settles to the bottom, which is a sand that has no sharpness, and the grains are of uniform size; the sand will drop to the bottom very quickly; whereas, a sand well graded in size, a sharp sand, does not have the tendency to settle in the mortar. Take, for example, ground Indiana limestone with cement, in the proportion of 4 to 1, and make it as thin as cream, or as thin as pancake batter, and while with a sand mixture it is difficult to keep the sand from going to the bottom, with the ground limestone there is no such trouble. Again, with ground marble, of high specific gravity and density, there is a great deal of trouble.

Ques. That would tend to bear out, then, the experience in the case of the East River tunnel?

Ans. — If you experience a thing of that kind, use a little less water.

Ques. — Grout that has to be pumped through a force pump has to be of about the right consistency, rather fluid?

Ans. — I should say the difference of result is determined mostly by the character of the sand or the stone dust.

Ques. — Would that difference in the quality or character of the sand influence you in fixing the amount of the water to be used in concrete?

Ans. — In extreme cases, but you would not encounter that difficulty with the ordinary concrete; with thin grout that has to be pumped you very likely would.

Ques. — There is a general impression to the effect that the concrete you describe as very wet, a fluid concrete, can be placed without voids, but I have seen some notable exceptions, and it is accounted for wholly in the act of placing it. Where the concrete is dumped from a steel tray wheelbarrow there is a natural separation between the mortar and stone, and where there is no opportunity to roll out from it the stone will cling to the wheelbarrow, and you will find the same voids in wet concrete that you will find in comparatively dry concrete well run.

Ans. — I agree with you entirely on that.

Ques. — I was impressed with that by a man telling me about laying a re-enforced concrete floor. There was made a special mixture to embed the steel re-enforcements, and in order to secure a thorough bonding between the mortar and steel, it was made pretty wet, and then filled with fine graded concrete, and he told me some time after the frame was removed that he ran his hand under one of the girders and it came down filled with sand. Now, that in a way seems to bear out my contention that the sand goes to the bottom and the cement floats.

Ans. — I think there is no question but that that result would be experienced in excessively wet grout or concrete, either one, where you have a large surplus of water. The difference in specific gravity and fineness between the sand particles and the cement particles would be very noticeable.

Ques. (by Mr. Parker). — I would like to ask Mr. Parmley how small sewers have been built in monolithic work.

Ans. — About 4 ft. The objection to making them smaller is almost entirely from the contractor's side. They say that in a ditch where they have timber braces and cheek pieces, with the thin side walls requred for a small sewer, it is a very cramped place in which to work, and there is danger of a chunk of clay falling into the side wall, through the carelessness of some workman and making future trouble for the contractor. These things cause him to object to it.

Ques. — You spoke of the joints in the block concrete. I should think you would experience the same trouble in getting them tight that they do in making the joints of a sewer pipe; how is that?

Ans. — In the case of sewer pipe with bell and spigot joint, it is difficult to get the cement forced into the small annular space, sometimes only an eighth of an inch wide. With the block sewer the cement is not forced in a horizontal position into thin crevices, but it is projected downward into a crevice about an inch wide.

Ques. — Are your invert blocks so rabbeted that you put the concrete in at the top?

Ans. — I prefer ordinarily not to rabbet the bottom block at all, but to make a plain butt joint so the mortar will be forced both upwards and downwards as the block is pushed into position.

Ques. — Do you find that you can depend on workmen to do that with sufficient skill?

Ans. — I think you can be more sure of it because it is within the plain vision of the workmen. At the same time it is where a man on the top can also see it.

The Chairman. — We have heard a great deal from the engineers, and now perhaps it would be well to hear from the contractors. Mr. Gow has had a good deal of experience, and we shall be pleased to hear from him.

Mr. Gow. — Mr. President, I don't know but there is something to be said on both sides of the question, and I think, as a general rule, that what is of advantage to the contractor in the matter of facilitating his work is also indirectly of advantage to the engineer. I think, too, there is justice in the criticisms that contractors sometimes make of engineers, or at least of some engineers, that too often they are guided by the results of laboratory tests, a fact that is brought to my mind in regard to the subject of wet concrete. It is true, of course, that contractors as a rule do prefer wet concrete, and I think that at times a proper consideration is not shown to their judgment in that respect. There are several reasons why we do prefer wet concrete from the practical standpoint. In the first place it is almost impossible where the conditions are such that a large amount of work is being done at one time to so control the laborers in their operations as to get the results of mixing that can be obtained in simple laboratory tests, and the result is, that in the turning of the concrete, for instance, we often get an accumulation of rich concrete in one part of the pile and the separated stones around the edges, perhaps, and in putting it into place it often happens at the last end of the batch there will be several shovelfuls of stones thrown in. If the concrete

is wet, these stones can be rammed into and embedded in the soft mortar; whereas, if we are compelled to use a dry mixture, it is almost impossible to so manipulate the concrete as to obtain a homogeneous mass. Then, too, in the case of thin walls, and more particularly in the case of re-enforced concrete, where the steel and re-enforcing bars are in the way, it is impossible at times to properly spade the work and bring the mortar to the surface. There is a tendency at the lower half of the ring for the stone to gather against the forms, and unless the concrete is quite wet, the only way to bring the cement there is to so spade the concrete as to flush the mortar to the front, or rather push the stones back into the mortar, which is a difficult matter with dry concrete in a narrow space. At the same time we frequently find conservative engineers who stick to the old rule, although I think most engineers are now given to the opinion that wet concrete is better. Some years ago on the construction of the old subway work, we had a rule for the guidance of inspectors. The test of wetness of concrete was whether or not the moisture appeared on the exterior faces of the form. If it did, the concrete was too wet; and we found that in order to prevent this it was necessary to merely dampen the mixture, which made it extremely hard to manipulate, especially if the stones tended to gather in bunches, and the contractors at least were unanimous in the opinion that if they were to be held to strict accountability for homogeneous work, they should be allowed a moderate amount of wetness. My own opinion is that the best results are obtained by a mixture of about the consistency of liver, something that will quake, a mortar that will allow the stone to go into it.

I have had some experience with the construction of concrete sewers. In the construction of the East Boston tunnel work, and also a portion of the Washington Street tunnel, it was necessary for a greater part of its length to construct sewer riders at the side walls or haunches, and for the most part this construction was incorporated into and formed a part of one of the walls. It was necessary to build a back wall that formed the waterproofing surface, and usually the design was so drawn that the sewer construction formed a part of this back wall. Probably a greater amount of concrete was used than was theoretically necessary, which was done for other reasons than the mere design of the sewer.

There is a peculiar feature attaching to one case in State Street in connection with the East Boston tunnel. An egg-

shaped sewer, 3 ft. 3 in. by 2 ft. 2 in., was constructed for a distance of approximately 1 500 ft., and it was necessary, on account of the conditions and methods of operation, to construct it in short sections, usually 16 ft., and oftentimes shorter lengths. This necessitated a great many joinings which were made in the usual manner of putting in roughing pieces and taking them out afterwards. On inspecting the sewer at completion it was found that there were absolutely no cracks, it being naturally expected in a structure of that sort, not reenforced either longitudinally or transversely, that there would be some cracks from shrinkage. We found them in the tunnel structure itself, which is of monolithic construction, and naturally expected to find them in the sewer, but close inspections revealed no such cracks.

The Chairman. — How long a section was that?

Mr. Gow. — That was pretty nearly 1 500 ft. It seemed possible that shrinkage cracks would appear eventually, if not at that time.

Speaking about some of the smaller sizes, we had occasion recently, on La Grange Street, in connection with the Washington Street tunnel construction, to build a sewer there. The conditions were such that the sewer design was of secondary consideration, the space being so limited between the building line and the back of the subway walls, and the design finally adopted was a 36 by 18-in. structure, reinforced by rectangular frames of strap iron surrounding the section and spaced 2 ft. on centers. The matter of forms came up, and it seemed to be quite a serious obstacle. The fact that the sewer was only 18 in. wide would necessitate, if wood was used, almost entirely filling the space with forms, but in accordance with an idea of Mr. Carson, chief engineer, we split an 18-in. Akron pipe, and used one section for the invert and one section for the arch, putting straight board sides between with a few braces, which made a simple form, although the matter of expense of the channel pipe in ordinary construction would be greater than some other systems. I have often thought if occasion arose where there was sufficient length of sewer of uniform section to be built of concrete, that some form of steel centering sectionally constructed could be used to great advantage. The great trouble to my mind in putting in concrete, and especially wet concrete, is the inability to get tight forms. I cannot conceive how there can be much difficulty in getting good homogeneous concrete if it is put in moderately wet, provided the

grout, that is, the cement, does not leak out through the forms. That is one of the greatest difficulties we have had with concrete sewers, where the conditions have necessitated wet concrete.

MR. PARMLEY. — The use of a paper lining will prevent that.

MR. GOW. — We have tried paper liinng in exactly the way you have referred to, but it has always seemed necessary to spade the concrete, and in so doing the paper was invariably cut in some way, a careless workman possibly dropping a sharp tool on the center and cutting the paper. It is more customary in this locality to use some kind of sheet iron covering, but it occurred to me that a convenient steel form might be used, made of angle iron ribs, bent to the required radius, or radii (if there were more than one centre), and on that some thin sheet plate iron bent, the plates being used in sections, say a section for the bottom of the invert at the water line, one for each side of the invert, and two sections, perhaps, for the arch; that is, a minimum number of sections that could be lapped together and fastened with some sort of button iron arrangement to the angle or edge of the rib. The angle iron rib might be bolted at the springing line to facilitate removal. The plates being thin, they could be easily removed from the concrete, and the whole form could be advanced successively through the other work, if necessary. It would also require a minimum space on the inside of the sewer to allow access to and from the different parts of the work.

The principal advantage to the contractor of the use of concrete in the place of brick has been the fact, as mentioned before to-night, of the trouble with bricklayers. This trouble does not rest so much with the bricklayers themselves as with the prevailing conditions of the bricklayers' trade, which is beginning to make the price exorbitant. If the contractor has a long stretch of work on hand in a busy time of the year, it is almost impossible oftentimes to obtain a sufficient number of bricklayers to carry on the work at the rate of progress necessary, and at such times the contractor cannot always command the best class of labor. The good men always go to work first, and the poorer men are left to the last, and are, therefore, the only mechanics of that kind available. In that case you are confronted on the one hand with the fact that the engineer requires first-class work, and, on the other, with the inability to get first-class mechanics to do it. We have had that expe-

rience several times, and it is an unpleasant one. The fact that the bricklayers' union prohibits the use of apprentices on sewer work is rapidly narrowing the number of available men, so that in a few years it would seem that with brick construction it will be impossible to carry on very much work.

There was some mention made to-night in regard to the placing of concrete against asphalt, and it reminded me of a peculiar experiment we once tried in connection with making centers water-tight. It was suggested we could get them tight by covering them with asphalt. Our experience had always been in putting asphalt on to concrete that it is impossible to get a good bond between the asphalt and the concrete, even though the concrete is thoroughly clean and dry; that is to say, it is almost invariably the case that the asphalt can be torn up in sheets, there being no bond between asphalt and concrete. We tried some asphalt on the centers and put in concrete against them, and on removing the centers, when the concrete had set, the concrete adhered to the asphalt so that we drew out large blocks of concrete with the centers. It appeared, therefore, that asphalt applied to concrete would not bond, but concrete applied to asphalt would bond. I have since seen it stated that by cutting the asphalt with naphtha or some such material, and painting it on first, getting a material that will adhere to the concrete, the asphalt can be applied and made to bond.

The Chairman. — The city of Worcester has done more or less concrete work, and Mr. Eddy, the superintendent of sewers there, has some notes which may be of interest.

Mr. Eddy. — Mr. President, it is rather late to start with a discussion of concrete sewers. We have dealt in Worcester almost wholly with small sizes, almost entirely under 5 ft. diameter. We have one interesting instance, however, of the "obsolete" form of the stone sewer being built in connection with the present concrete type. Some twenty-five years ago, a concrete invert was laid in a sewer 18 ft. wide and 13 ft. high. I examined that sewer some little time ago and found the concrete was in very good condition. It was made of natural cement. It had worn somewhat rough, but I think it had not worn to a depth of an inch, and my impression is that the wear amounted to quite a little less than an inch. We have built concrete sewers lately of monolithic construction without steel re-enforcing down as low as 24-in. One of the chief points which we make in getting good work is to use a very wet concrete and to use a fine stone. We started in by using the ordi-

nary No. 1 crushed stone, or something corresponding with that, but found it was too coarse for the thickness of the walls we had to construct, and we now use entirely the No. 2, or what would correspond to the size of chestnut coal. We mix the sand and cement in a mortar bed, mix it pretty wet and shovel it on to the stone, and then turn it, and it gives us a wet, homogeneous concrete, which has turned out very well. We, however, use underdrains in all sewer work, and insist on pumping a considerable length of time after the concrete is put in place, if the underdrain is to be discontinued.

In regard to cost, our work is all hand and day work, with a minimum wage of $1.85 for eight hours. We find that the concrete in the arch invariably costs more than in the invert, undoubtedly due to the extra outside forms used. We find also a great difference in the economy of the job whether the foreman keeps his outside forms set true, or whether he places them haphazard. In illustration of that, I noted where in one case the concrete measured in the batch was 120 per cent. of the concrete which the section actually called for. The foreman was whipped into line, with the result that the next two sections gave us 87 per cent. of what the section called for, so it makes a good deal of difference in this kind of work whether the forms are out of position 2 or 3 in. or not. It is very easy for the foreman to walk along the top of the trench and not see that the forms are improperly set.

We have found as an average that our concrete, including centers, costs about $7.55 a cubic yard in place, that is, with hand mixing, and using crushed stone, which costs $1.75 per ton.

Mr. Worthington. — What cement went into that $7.55 mixture?

Mr. Eddy. — It is Portland cement, and most of it was 1, 2½ and 4 mixture.

SEWAGE PURIFICATION WITH SPECIAL REFERENCE TO THE PROBLEM IN OHIO.

By R. Winthrop Pratt, Member Boston Society of Civil Engineers.

[Read before the Toledo Society of Engineers, April 21, 1905.]

At the risk of telling the members of this Society something they already know, I am first going to give a brief account of the general history and theory of Sewage Purification.

As long ago as the time of Moses, the subject of sewage disposal was an important one. Under the law of Moses all unclean matters were to be carried outside the camp and burned. The necessity for some such disposal as this, it is said, is fully appreciated by those who have visited Eastern villages in the present age and have seen the unremoved heaps of decomposing and disease-producing filth.

But burning was not a practicable way of disposing of all kinds of refuse, and therefore waste matters were committed to earth (Deut. xxiii: 12, 13), which method of sewage disposal has been continued in various forms up to the present day. Even the wandering tribes in the early days were careful about disposing of their refuse, in order not to pollute the streams and springs which were used for water supply. This was a comparatively simple matter, as the wastes were small in quantity and were largely solid rather than liquid in character.

With more modern civilization, the out-door closet, dry-pail system and cesspool became the standard methods of disposing of sewage, as they still are in the smaller villages of to-day.

When, in the nineteenth century, public water supplies, furnishing abundant quantities of water, became more common, and the wastes of communities became greatly diluted, thus creating the necessity for sewers, then the problem of sewage disposal became much more difficult, at least with those communities which, either through self-respect or through legal restraint, were prevented from polluting the water courses of the country; and methods of sewage purification, in the modern sense, began to be worked out.

The Composition of Sewage.

Generally speaking, sewage is water, polluted principally by organic, but also by inorganic, waste substances. An average

city sewage consists of 99.8 per cent. to 99.9 per cent. pure water and 0.1 per cent. to 0.2 per cent. solid matter. Of this solid portion, less than half is organic matter. The offensive matter in sewage therefore amounts to only a small fraction of 1 per cent. of the total weight of the sewage. But this small portion is largely in solution, or is suspended in a finely divided state; which fact is, at least, a partial explanation of the difficulties of sewage purification.

The polluting substances are made up chiefly of urine, fecal matter and the various kinds of household wastes, but frequently there is a certain amount of manufacturing refuse present; and if the sewer system is built on the combined plan there will be at times also a large amount of rain water, carrying with it street washings, sand and débris of various kinds. The more complex the nature of the sewage, due to either organic or inorganic matters, the more difficult it will be to purify. Even the character of the water supply of the city has sometimes an important bearing on the problem.

Chemically speaking, the organic contents of the sewage consist of nitrogenous and carbonaceous substances. These substances, and especially the nitrogenous matters, are constantly subjected to the action of enormous numbers of bacteria, tending to purify them, as described below.

Methods of Purification.

All practical processes for the thorough purification of sewage depend, at least for their final stages, upon bacteria or upon chemical changes induced by bacteria. These bacteria are present in the sewage and also in the filtering material, and their function is to break down the offensive organic matter and to convert it, or to begin to convert it, into harmless mineral matter. Pasteur divided them into two classes — aërobic and anaërobic. The aërobes work best when the sewage is exposed to air, and produce oxidation; the anaërobes work best without air and produce decomposition.

In the usual course of transition from organic matter to mineral matter the anaërobes are, at first, the most active, and decompose or break down the complex compounds into simpler and more readily oxidizable compounds; while during the latter part of this transition, the aërobes are most active and the oxidizing or mineralizing process is completed. The anaërobes pave the way, as it were, for the aërobes.

Sewage purification works should therefore, theoretically, be so designed as to allow each class of bacteria to work at the

proper time, and in the environments most suited to it. But in actual practice there are conditions, relating, usually, to economy of construction and efficiency of operation, which may warrant deviations from purely theoretical plans. The above principle should, however, always be kept in mind.

The chief methods for purifying or partially purifying sewage are broad irrigation, intermittent sand filtration, contact beds, continuous or sprinkling filters, chemical precipitation, septic tanks, sedimentation, and strainers of coarse material. The first four are final or complete processes while the last four are preliminary or partial processes. Sewage works almost invariably include two or more of the above methods, —usually a preliminary process, followed by one or perhaps two final processes. With certain methods a preliminary treatment is absolutely essential.

Methods of disposing of sewage by discharging it into large bodies of water might, in a certain sense, be classed under sewage purification. Such methods will not, however, be included in the present discussion.

Final or Complete Processes.

Broad Irrigation.—This method is perhaps the oldest and is also the most simple in principle. It consists in distributing the sewage, by means of ditches, over ground which is usually under cultivation or is devoted to grass or pasture land, the sewage being absorbed by the soil and by the crops. Unless the ground is exceptionally porous and thoroughly underdrained, only a comparatively small amount of sewage per unit area, say 5 000 to 15 000 gal. per acre per day, can be disposed of in this manner. This means, in a rough way, that one acre has to be provided for each 100 persons tributary to the sewers. When the sewage is treated by chemical precipitation or other means before being applied to the land, the rate of application may be considerably higher.

A large area of land, within reasonable distance of a city or town, must be available if this method is to be used; and in operating such works considerable attendance is necessary. The receipts from the sale of crops often largely offset the cost of operation, but only in rare cases do sewage farms appear to be operated at a profit. The variation in the capacity of the soil, due to rainfall, causes serious fluctuations in the amount of sewage which can be disposed of and makes it necessary sometimes to suspend the purification of the sewage in order to avoid over-dosing the crops.

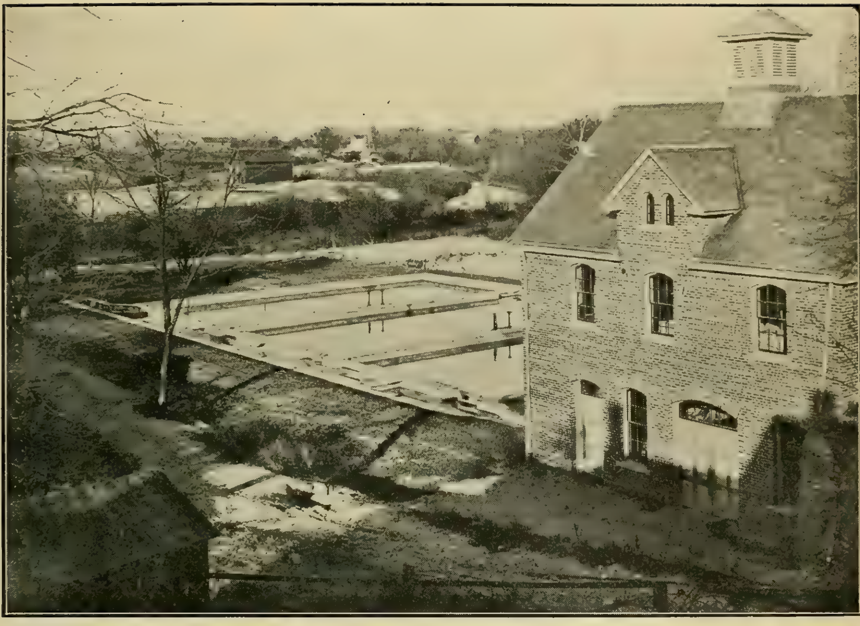

Fig. 1. Alliance, Ohio; General View of Chemical Precipitation Works.

Fig. 2. Canton, Ohio; General View of Chemical Precipitation Works.

FIG. 3. EAST CLEVELAND, OHIO; VIEW OF AERATORS WITH EFFLUENT WELL IN BACKGROUND.

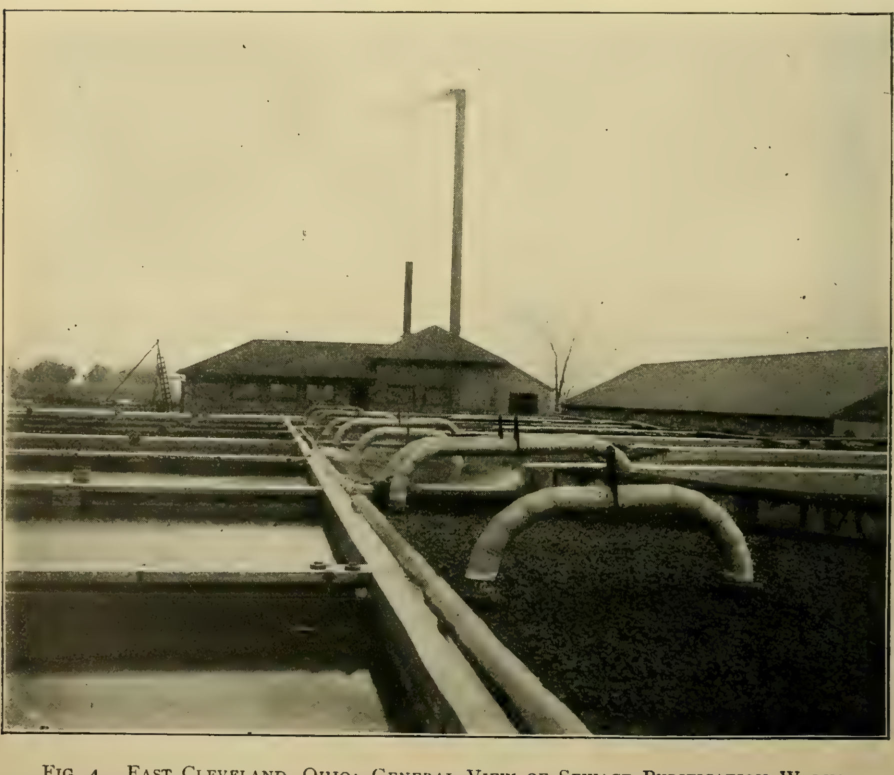

FIG. 4. EAST CLEVELAND, OHIO; GENERAL VIEW OF SEWAGE PURIFICATION WORKS, SHOWING AIR DUCTS LEADING TO PRIMARY AND SECONDARY FILTERS. SEPTIC TANK ON RIGHT, AERATORS ON LEFT.

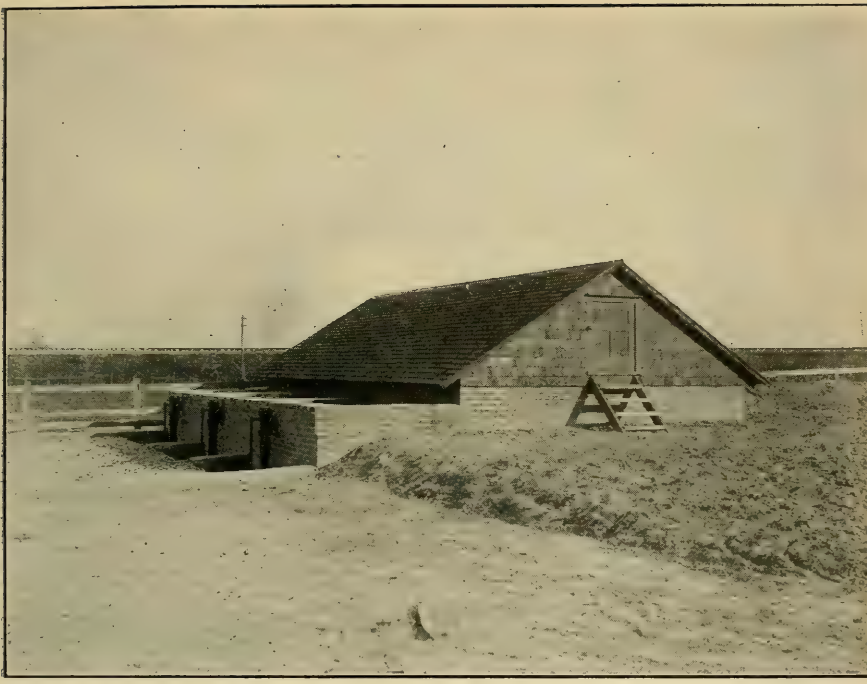

Fig. 5. Kenton, Ohio; View of Septic Tank, "Dosing Filters" and Upper Portion of "Wave Beds."

Fig. 6. Kenton, Ohio; General View of "Wave Bed" System. Effluent is Collected in Gutter Extending Across Lower Ends of these Beds.

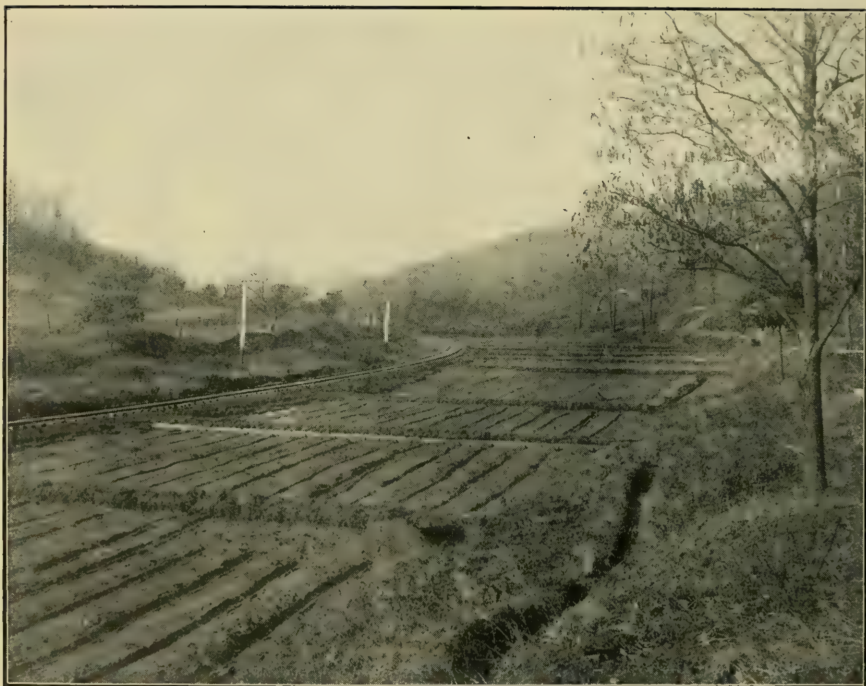

Fig. 7. Boys' Industrial School, Lancaster, Ohio; General View of Filter Beds.

The two largest sewage farms in the world are those at Paris and Berlin where there are respectively 13 100 and 17 500 acres under irrigation. There are also several large ones in England. The Berlin farm generally yields a profit each season, but the Paris farm requires a large annual expenditure. It should be remembered that the sewage of these as well as of most European cities is more concentrated than American sewage and hence is better adapted to this process.

Sewage irrigation in the arid portion of the western United States has been successful because the rainfall is so slight during most of the year that the ground and crops are able to absorb large amounts of moisture. But here the purification of the sewage has been secondary to the cultivation of the land.

The effluent of a broad irrigation area as it flows from the underdrains, or appears in the form of springs at some nearby point, is, with favorable soil and a properly cared for plant, as highly purified as any filtration process could make it. The effluent from the sewage farms and especially from that at Paris is said to be used by the attendants for drinking.

Under broad irrigation might be included sub-surface disposal or the distribution of the sewage by means of underground pipes, having open joints. This system, however, is only adapted to private residences and very small communities.

Intermittent Sand Filtration. — This method is a modification of, or an evolution from, broad irrigation. The process and its fundamental theories were thoroughly worked out, and the possibilities of its application made known to the world, by the Massachusetts State Board of Health, in a series of experiments, which are considered classical.

The principle of "nitrification" or oxidation, as applied to sewage purification by filtration, was suggested in 1872 when E. Frankland stated that "a filter must not be considered as merely a mechanical contrivance, the process carried on being also chemical"; but it remained for the Massachusetts State Board of Health to thoroughly explain this, and thus lay the foundation for modern methods.

With intermittent sand filtration, the sewage is filtered through specially prepared beds of sand 3 ft. to 5 ft. deep, at rates of 50 000 to 150 000 or more gal. per acre per day, depending largely upon the amount of suspended matter removed by preliminary processes. This rate is much greater than those possible with broad irrigation; hence the required area is pro-

portionately less. The sewage from 500 to 2 000 or more people can be purified on one acre.

As suggested above, the purification is not effected simply by the straining action obtained by passing the sewage through the sand, but is due principally to the action of "nitrifying bacteria" which live in the sand or which make their home there soon after the filter bed is put in operation. These bacteria are aërobic and must, therefore, be provided with an abundance of air, if they are to do their most efficient work. For this reason, it is essential that the sewage be applied to the filters, intermittently or in "doses"; and the filter allowed to thoroughly drain between the doses, so that the air can readily pass into it. The size of the sand is, of course, also an important factor.

Intermittent sand filtration is the method used almost exclusively in the Eastern States and it is also used in the Middle West where proper material is available. The resulting effluent is highly purified, and the simplicity of the process makes it very reliable.

Contact Beds. — The absence, or high cost, of sufficient areas of land available for broad irrigation and of material suitable for intermittent sand filtration, created the necessity for some method which required relatively small areas, and with which coarse material, such as coke, coal, slag or broken stone, could be used for filtering medium. The contact bed was therefore brought into use, in England, some ten years ago. A contact bed consists essentially of a water-tight basin filled with coarse material. After closing the outlet, the basin is allowed to fill with sewage which remains in contact with the material (coke, coal, slag, cinders or broken stone) long enough for the bacteria living thereon to purify the sewage. The contact bed is then slowly drained. The bacterial action is similar to that taking place in an intermittent sand filter, but the resulting effluent, though usually not putrescible, is by no means as well purified as a sand filter effluent.

Before being applied to contact beds the sewage is subjected to some preliminary process in order to remove as much suspended matter as possible and thus prevent the speedy filling of the voids of the filter. Such clogging sometimes occurs, however, and means a large item of expense in cleaning the material.

The rate of treatment varies from one to three fillings of the bed or "contacts" per day — this being equivalent, on a bed 3 ft. deep, to 330 000 to 1 000 000 gal. per acre per day.

Sprinkling or Continuous Filters. — These filters are of quite recent date. Though used to a considerable extent in

England, there are, as yet, but two or three in this country. In surface appearance, they resemble contact beds since both are composed of similar coarse material — the sprinkling filter material, however, being sometimes larger. But the sprinkling filters are usually deeper and the principle of operation is quite different. Instead of completely filling the filter (as in the case of the contact bed), the sewage is sprinkled or sprayed evenly over the surface and allowed to continuously trickle downward through the material for perhaps several days at a time. The purifying bacteria establish themselves upon the filtering material.

Rates as high as 2 000 000 to 3 000 000 gal. per acre per day have been used. This is more than ten times the rate possible with sand filters. The effluent produced compares very favorably with contact bed effluent, though decidedly inferior to a sand filter effluent. The chief objection to their use in cold climates has been the liability of freezing of the distributing devices; but it is quite possible that means will be devised for overcoming present objections and that this process will be used, with satisfaction, even in freezing weather.

Preliminary or Partial Processes.

Chemical Precipitation. — The treatment of sewage by chemicals has been in use for at least one hundred and fifty years and many patents for chemical processes have been taken out, especially in England. At best this is only a process of clarification rather than purification, and bacterial action takes no part in it.

In chemical precipitation lime, copperas, or other chemicals are added to the sewage and these decompose or react with certain mineral constituents in the sewage (or rather in the water of which the sewage is almost entirely made up) forming a precipitate which, when allowed to settle out in properly proportioned tanks, envelopes and drags down a large portion of the suspended matters. But the offensive matters in solution are only slightly affected by this process.

The total organic matter removed, including both that in solution and in suspension, is 50 per cent. or 60 per cent. The effluent is putrescible, and unless there is a large body of water to receive it, further purification is necessary.

The cost of chemical precipitation is generally large in comparison with other methods effecting the same amount of purification. This high cost is due to the cost of the chemicals

and to the necessity for handling and disposing of large amounts of sludge.

The sewage from London, England, population 4 536 541, is treated by chemical precipitation at the largest sewage works in the world. The daily amount treated is 300 000 000 gal. and the precipitated sludge amounts to 8 000 tons per day. Six large vessels are used to convey this sludge out to sea. The question of abandoning chemical precipitation at London, however, and replacing it by septic tanks and contact beds, is being strongly agitated.

Sedimentation. — Perhaps the simplest way of removing a portion of the coarser and heavier suspended particles from sewage is to pass it, after screening, through settling tanks holding several hours' flow. The sedimentation taking place, especially in the case of sewage containing street washings, effects a partial clarification of the sewage and is a decided advantage to whatever form of filtration may be used subsequently; 30 per cent. or more of the suspended matter may be removed. The sludge deposited in the bottom of the tank may be drawn off when necessary on to special areas or filters and allowed to dry; or if the case warrants, it may be pressed into cakes and burned or composted. The same effect is secured by storing the sewage in a reservoir for certain periods, as is done in certain small communities, where the sewage must be pumped, but where continuous pumping is not feasible. The accumulations in the bottom of such a reservoir, due to sedimentation, are pumped out last and may be treated on separate filters.

The Septic Tank. — If the sludge or solid matter in the bottom of a settling tank be allowed to remain there for a sufficient period, it is attacked by anaërobic bacteria and changed, to a greater or less extent, into liquid or gaseous forms, thus reducing the amount of sludge to be handled. A tank where this process takes place is called a septic tank.

The principal action therein, it is seen, is two-fold, — a simple sedimentation and a liquification and gasification, through bacterial agencies, of the matter deposited. In addition, however, there is a certain change in the character of the suspended matter remaining in the sewage during its passage through the tank, and also in the soluble organic matter. The total amount of organic matter, both soluble and suspended, removed by this process may be as much as 40 per cent. or 50 per cent. In a general way, a septic tank should hold from 8 to 24 hr. flow.

Another advantage of either a settling or septic tank, but more especially the latter on account of its larger size, is, that an equalization in the character of the sewage is effected and subsequent final purification thus facilitated.

The question of covering a tank should be decided by local conditions. Covers are not essential to septic action, as was at first supposed, but they are very desirable if odors from the tank would be any objection. It is also possible for the sewage in uncovered tanks to freeze in winter; but this depends upon the winter temperature of the sewage, which in turn is affected by the temperature of the water discharged into the sewers. At Saratoga, N. Y., during a severe winter, the scum on the surface of the sewage in covered tanks was frozen several inches while some open tanks at Delaware, Ohio, were not frozen. Saratoga has a surface water supply while Delaware has a ground supply.

In actual practice, there have been factors which have prevented the septic tank from being a success in all cases. Chief among these have been, abnormal character of sewage; incorrect design of tank, as regards inlet, outlet and depth; too small a capacity; or too large a capacity. The first three faults may cause the tank to quickly fill up while the last is apt to decompose the sewage to such an extent that foul odors are created; and also to prevent the sewage from being oxidized in sand or other filters.

The widely varying results with the septic tank make it a process only to be adopted, if at all, after careful study of all the factors involved.

The popular opinion seems to be that the septic tank is a complete method in itself. This is wrong. The septic tank is meant to be simply a sludge destroyer and, to a certain extent, a clarifier. The effluent is always ill-smelling and putrescible.

Strainers. — The plan of passing crude sewage at high rates through strainers of coarse material has been studied experimentally by the Massachusetts State Board of Health for some years, but few such strainers have been attempted in actual practice. In a strainer, the action is purely mechanical, and a deposit of organic matter quickly occurs at or near the top so that the filtering material requires frequent cleaning and replacing. With the present information, strainers appear to be too expensive for general use but might be used economically in places where they could be made of coke or coal and

where the clogged filtering material could be dried and used for fuel.

The Best Method.

The question is often asked, What is the best method of sewage purification? An answer to this question is impossible without first asking several others, such as,—For what sized city? In what climate? What kind of sewage system? What is the character of the sewage? What degree of purification is desired? What materials are most available? Where must the plant be located with reference to habitation?

If we should install one system for all cases we should certainly meet with many failures and go to much needless expense.

From the above descriptions of the various methods, it will be seen that they have been worked out largely to meet the requirements of different conditions; and now that we have all the processes at our command, the first duty of the engineer, in making his recommendation for sewage purification works, is to decide, after careful investigation, which of the processes or combination of processes is best adapted for the case in hand.

If by the "best method" is meant the method which will give the greatest purification, then we may say that, aside from broad irrigation, which is rarely desirable, intermittent sand filtration, properly operated, will yield the finest effluent; and therefore where the purified sewage must be discharged into a stream used for water supply purposes, sand should be used as a filtering material.

Even where a highly purified effluent is not essential, if there is no great difference in the cost and if a favorable site can be secured, intermittent sand filtration should be adopted. The reliability and simplicity of operation of this system are characteristics which make it especially to be desired.

In most cases, however, if the sewage is purified to a point beyond the putrescible stage, so that it will cause no pollution of the stream, which is offensive to sight or smell, all requirements of purification will be met. Where judgment of the effluent by this "non-putrescible," standard is allowable, and where the sewage is not extremely abnormal, then any of the several different materials and methods may be used, the choice in such cases being based upon available site and cost of construction and operation.

Value of Sewage as a Fertilizer.

When sewage can be applied to land which would otherwise be unable to produce crops, on account of lack of moisture, then the sewage has a decided fertilizing value; but such value is due to the water in the sewage rather than to the nitrogen, phosphates or other fertilizing ingredients. This is the case in the arid regions of our Western States — especially in California, where sewage is used for irrigation.

In the eastern part of this country and also in England sewage is used to fertilize crops as described above under broad irrigation; but the value of the crops rarely equals the cost of applying the sewage and it is a question whether the crops would not have been better if treated with pure water or not watered at all.

Crops are grown on certain intermittent sand filter beds in the eastern part of this country, and here the sewage has a value in that it makes the sandy filtering material support the growth of vegetables the sale of which helps pay for running the plant. But such purification plants cannot be run at a profit; and furthermore the raising of crops reduces the capacity of the sand for purifying sewage. The dried sludge scraped from sand beds is rarely, if ever, used to advantage as a fertilizer.

Chemically precipitated sludge, though containing, theoretically, valuable ingredients, has never been a source of revenue, as far as I am able to determine; although the statement is sometimes made before chemical precipitation plants are installed, that the farmers will buy and haul away the sludge. It rarely happens, however, that a farmer will haul it away unless he is paid for doing so.

Many schemes have been suggested or tried, in the past, for reclaiming certain substances from sewage for the purpose of manufacturing commercial fertilizer and grease, and making a profit upon the investment. One such scheme was proposed but recently in Ohio. To show the fallacy of attempting such a process, we have only to consider that 1 000 000 gal. of sewage which, at 100 gal. per capita, represents the daily discharge from 10 000 people, contains only 2 to 3 tons of solid matter. Of this amount of solid matter not more than one ton is organic; and about one-half of this one ton is in solution.

The cost of treating 1 000 000 gal. of sewage by evaporating or reducing processes, for the purpose of reclaiming one ton of

fertilizing ingredients valued at $5 or $10, would clearly be prohibitive.

The cost of obtaining fertilizer from those substances which can be screened from the sewage would be less than the above. But the actual output of a plant built for this purpose would certainly not be sufficient to pay for operating unless the sewage from many hundreds of thousands of people could be used. It is the opinion of unprejudiced investigators that such a scheme would not be feasible under any circumstances. It surely would not effect any material purification in the sewage as all offensive matters in solution would be allowed to pass on.

Status of the Problem in Ohio.

The first sewage purification plant in Ohio was the chemical precipitation plant, built at Canton in 1893. In 1898 there were 7 plants in use by cities, villages and public institutions. At the present time there are 32 in use. The methods employed are shown in the accompanying table:

TABLE A.

Tabular Statement of the Methods Employed at the 32 Sewage Purification Plants in use in Ohio, January, 1905.

(Of the 32 plants, 17 are Municipal and 15 Institutional.)

No. of Plants.	Population actually using Plants.	Preliminary Treatment (preceded by screening in all but three cases).	Final Treatment.
4	2,800	None	Intermittent Sand Filtration or similar treatment.
3*	5,000	Sedimentation (with continuous flow to filters)	Intermittent Sand Filtration or similar treatment.
2†	150	Sedimentation (followed by application of sewage to filters by flush tanks)	Intermittent Sand Filtration or similar treatment.
7	9,275	Flush Tanks or Storage Reservoir .	Intermittent Sand Filtration or similar treatment.
1	100	Septic Tank	None.
3	2,500	Septic Tank	Intermittent Sand Filtration.
2‡	500	Septic Tank	Intermittent Filtration through Coke.
6	13,500	Septic Tank	Contact Beds.
1	5,000	Septic Tank	Continuous Filtration with forced æration.
2	16,000	Chemical Precipitation	None.
1	4,500	Chemical Precipitation	Contact Beds followed by Intermittent Sand Filtration.
1*	4,500	Chemical Precipitation	Sewage discharged over land to creek.

* Oberlin is placed in two different classes.

† Includes Hardin Co. Infirmary subsoil plant.

‡ Includes "Wave Beds" at Kenton.

Proposed plans for 30 more plants, nearly all municipal, have been approved by the State Board of Health and, in addition, plans for several other cities, notably for Columbus, are in course of preparation. When the Columbus plant is in operation, about 275 000 people or 14 per cent. of the urban population of the state, living in cities or villages of 4 000 or over, will be provided with sewage purification plants. This does not include the people using institutional plants.

In order to compare these figures with the corresponding figures for the entire country as worked out by Mr. George W. Fuller, it may be said, that of an urban population of 22 600 000 which live in cities of 4 000 or over, located upon inland streams or lakes, 1 100 000, or less than 5 per cent., live in cities provided with sewage purification plants. It is evident, therefore, that Ohio is considerably in advance of most states, along these lines.

The geological conditions in Ohio are such that sand or gravel in sufficient quantities, and suitably located for intermittent filtration areas, are rarely found. In regard to broad irrigation, the price of land is too high in localities near the cities, and furthermore, the rainfall in this state is such that the ground has little capacity for absorbing sewage. Those processes, therefore, which require as little area and as little filtering material as possible, have seemed most desirable. Chemical precipitation works were built at first, but for the last 6 or 7 years, since the septic tank has become so popular, it has been the usual practice to use such tanks as a preliminary process in connection with coke, cinder or sand filters.

There are now in use 12 septic tanks, while plans for 25 more have been made. The success of these tanks during the comparatively few years that they have been in operation, has been varied; but in all cases it appears that they have served, in a greater or less degree, to remove suspended matter from the sewage and thus enable it to be treated more easily by filtration. In some cases, however, offensive odors have been created; and in one case the accumulation in the tank has been so great that the expense of cleaning it out will be a serious factor. Most of the tanks have, however, been fairly efficient as sludge destroyers.

The contact bed has been used at 7 places, 6 of which are provided with automatic apparatus. In only 2 of these cases, however, has such apparatus operated successfully; but in 1 of the cases where the apparatus has failed to work, the amount

of sewage which required treatment has fortunately been so small that considerable purification has been effected as the sewage flowed continuously through the beds.

Although all plans for proposed sewage works must be approved by the State Board of Health, the Board has not, as yet, been able to make regular inspections of them after they are built. This is unfortunate, as the principal cause of their failure lies usually in poor operation rather than in poor design. The average municipal official thinks that his duty is performed when the construction of the plant is paid for. This idea is due to several causes.

First: The constructing engineer, on finishing his work, receives his pay and then leaves the plant entirely in unskilled hands. Some cities have lately, however, made arrangements to retain the constructing engineer for a period to insure the proper starting of the plant.

Second: A plant is often installed as the result of a lawsuit and the chief object is to spend as little money as possible, either for construction or maintenance.

Third: It is not fully realized that the character of the sewage and other conditions are ever liable to change, and that success at one time does not mean success at another, unless the most intelligent and constant care is used.

Fourth: The idea that automatic regulating apparatus can be left entirely without supervision. No apparatus has yet been installed which does not require more or less frequent inspection by some one who thoroughly understands it.

I would also point out here, that perhaps one of the fundamental reasons for the failure of sewage purification plants, as well as for the poor character of some other engineering works, is the fact that municipal officials, especially in the smaller cities, are fast coming to regard the engineer as a " necessary evil " or even as an unnecessary one. They fail to realize the importance of the work of the engineer, and therefore employ whoever sets the lowest price on his services, regardless of his value.

When an engineer, for the sake of getting sewerage work, makes his fee less than the work is worth, it is not probable that he intends actually to lose money by the transaction; consequently, he cannot afford to spend the proper amount of time in preparing plans or inspecting construction, to say nothing of looking after sewage purification works when completed. If the city officials could be educated to appreciate the advantage of thorough and high class engineering, and be willing

to pay for it on the same plan on which reputable doctors and lawyers are paid, there would be fewer unsatisfactory results.

Description of Some of the Principal Ohio Plants.

The following are brief descriptions of some of the largest and most interesting Sewage Purification Plants in Ohio. These and other plants are more fully described in the Annual Report of the Ohio State Board of Health for 1903.

Alliance.

Estimated population, — 9 500.

Estimated population using sewers, — 4 000.

Sewerage system consists of 15 miles of sewers built principally on the separate plan and having 1 000 connections. Sewers are underdrained only to a small extent.

Quantity of Sewage. — Average flow of sewage is approximately 800 000 gal. per day, all of which is passed through the purification plant.

Character of Sewage. — Principally domestic, but also con tains the wastes from two large iron working factories and gas works.

Date of installation of plant, — 1896.

Stream receiving Effluent. — Mahoning River; dry weather flow 3 cu. ft. per sec.

Method of Treatment. — Chemical precipitation. The precipitation tanks are 3 in number, each 80 by 40 and 6 ft. deep and having a total capacity of 420 000 gal. or about 50 per cent. of the average daily flow. About 1 350 lb. of lime are used each 24 hr. but this is not applied continuously. At the entrance to the tanks the larger matters are screened out. The flow through the tanks is continuous except when interrupted for cleaning, which occurs two or three times a week for the first two tanks and once a week for the last tank.

Results. — The plant is kept in operation throughout the year, but is at present overworked and effects very little purification of the sewage. The question of disposing of the sludge is becoming a serious one, and it is fast accumulating in heaps, near the plant. Odors from the plant have caused numerous complaints.

Cost. — The cost of construction was about $22 200. Annual cost, maintenance is a little over $2 000; about half of which is paid for salaries and half for fuel and lime.

Canton.

Estimated population, — 32 500.

Estimated population using sewers, — 11 000.

Sewerage system consists of 34 miles of domestic sewers having 2 144 connections. About a mile of the system is underdrained.

Quantity of Sewage. — The average daily flow is about 2 500 000 gal. per day, all of which is passed through this purification plant.

Character of Sewage. — Domestic sewage mixed with a large amount of ground water leakage.

Date of installation of plant. — 1893.

Stream receiving Effluent. — Nimishillen Creek; dry weather flow, 4 cu. ft. per sec.

Method of Treatment.—Chemical precipitation. Precipitation tanks are 4 in number, each 50 by 100 by 5 ft. deep, having a total capacity of 700 000 gal., or about 28 per cent. of the average daily flow. About 1 050 lb. of lime are used each 24 hr. The largest suspended particles are screened out before the sewage enters the tanks. It is necessary to draw off the sludge from the first two precipitation tanks three times a week and from the last two once a week. The sludge is then pumped from the sludge well on to neighboring fields and is occasionally plowed into the ground. It was formerly pressed into cakes but the quantity of sludge has outgrown the capacity of the press.

Results. — The plant is kept in operation throughout the year but is apparently out-grown; this being due in part to the large amount of leakage into the sewer system. The amount of lime used is sufficient for obtaining the best results and the stream receiving the effluent is more or less polluted. The field on to which the sludge is now being pumped is fast becoming overloaded and other means for sludge disposal are needed. The occupants of the few houses near the plant are said to have become accustomed to the odors from it.

Cost. — The first cost of the plant was $31 545 for which $5 000 was paid for land. Annual cost of maintenance is $3 850 divided as follows; Three men $2 100, lime $550, fuel $600, repairs, etc., $600.

Clyde.

Estimated population, — 2 600.

Estimated population using sewers, — 700.

Sewerage system consists of 3 miles of combined sewers

having about 125 house connections. A large portion of the sewers were built for land drainage only.

Quantity of Sewage. — The approximate average dry weather flow is 100 000 gal. per day; the maximum flow in wet weather is several million gal. per day, most of which overflows into the creek before reaching the disposal area.

Character of Sewage. — Domestic sewage, at times highly diluted by storm water and ground water; formerly the wastes from a sauerkraut factory and gas works were discharged into the sewers.

Date of installation of plant, — 1898.

Stream receiving Effluent. — Raccoon Creek; practically no flow in dry weather.

Method of Treatment. — Intermittent filtration upon four acres of very fine sandy clay divided into eight beds. At the inlet to each bed is a shallow box 5 ft. by 10 ft. by 1 ft. for the purpose of allowing some of the solid matters to settle out before reaching the surface of the beds. The beds are underdrained by lines of 4-in. pipe 16 ft. apart.

Results. — The plant is not used in winter. Four or five different inspections of the plant have failed to show a satisfactory effluent even when in use. This was due in part to lack of care in cleaning the surface of the beds; but the sauerkraut refuse, which consisted largely of strong brine, undoubtedly had a detrimental effect upon the purification of the sewage and it is very doubtful whether good purification could have been obtained, even with the best of care, as long as this waste was mixed with the sewage. The refuse from the gas works further complicated the problem. The plant was a source of odors, disagreeable to those living 1 000 ft. or more away.

It is interesting to note that the village brought suit against the sauerkraut company for interfering with the proper operation of the purification plant, and that the evidence at the preliminary hearing was so much in favor of the village that the sauerkraut company decided to make other disposition of its wates.

Cost. — Cost of the plant including land is $5 000. Amount spent annually for its care is $250.

East Cleveland.

Estimated population, — 6 000.

Estimated population using sewers, — 5 000.

Sewerage system consists of 40 miles of pipe sewers having 1 005 connections. Sewers are designed to receive domestic

sewage only, and are generally provided with underdrains. At some places in the city, storm sewers are laid in the same trenches with and above the domestic sewers.

Quantity of Sewage. — Estimated average dry weather flow is about 400 000 gal. per day, but this is increased by ground water, due largely to the leakage from the storm water sewers into the domestic sewers, to 1 400 000 gal. per day during certain periods. Sewage all passes through works.

Character of Sewage. — Strictly domestic; diluted at times by leakage into sewers.

Date of installation of plant. — 1899. Doubled in size and septic tank added in 1901.

Stream receiving Effluent. — Small intermittent brook.

Method of Treatment. — Septic tank and forced aëration. Plant designed according to theories first advanced by Waring. Sewage flows by gravity into a receiving well from which it is pumped into a septic tank holding 170 000 gal. or 10 to 12 hr. dry weather flow. The septic tank effluent is then treated as follows: First, by downward filtration or straining through 8 primary filters having a total area of 0.11 acres and containing 2.5 ft. of egg-sized slag; second, upward through 4 secondary filters having a total area of 0.055 acres and containing 2.5 ft. of similar material; and third, downward through two "aërators" or filters having total area of 0.46 acres containing 4 ft. pea coke, covered with a 4-in. layer of sand. The filters are all thoroughly underdrained by means of inverted half tile with open joints placed close together, resting on concrete floors; air is forced continuously into the underdrains by means of a blower located in the pumplng station.

The filters are operated continuously for periods of from three to ten days or until clogged.

Results. — As first built in 1899, when there was no septic tank and when the fresh sewage was applied directly to the primary filters, the result was to speedily clog these filters and necessitate their being cleaned at large expense. It is said that this result was due largely to the infiltration of storm water containing large amounts of clay into the domestic sewers.

Since the enlargement of the works and the installation of the septic tank, no thorough examination of the plant has been made; but it is understood that it has been necessary to wash the filtering material much less frequently than formerly, and that the effluent from the works has been, during a large portion of the time, clear and odorless.

The septic tank, however, has given rise to offensive odors, and the tank itself is filling up with sludge. When visited in winter the surfaces of the aërators were frozen and they were out of service; the sewage being passed through septic tanks and primary and secondary filters only. It is said to be practicably impossible to clean the surface of the aërators during cold weather; but on account of the rapid rate of filtration, these filters rapidly accumulate solid matter on their surfaces and need frequent cleaning.

The disposing of the sludge accumulating in the receiving well is also a serious factor.

Cost. — Land,	$12 500
Receiving well, machinery and first unit,	20 700
Septic tank, second unit and boiler,	17 900
Engineering and patent rights,	5 192
Total,	$56 292

The annual cost of operation, excluding capital charges, is as follows:

Two engineers (one day and one night),	$1 440
One extra laborer,	540
Fuel,	700
Repairs and extra help,	300
Total,	$2 980

GLENVILLE.

Estimated population, — 7 000.

Estimated population using sewers, — 4 500.

Sewerage system consists of 10.5 miles of domestic sewers having 850 connections. The sewers are designed to receive domestic sewage only, and are underdrained, but at one place at least a certain amount of storm water enters them.

Quantity of Sewage. — Estimated average daily flow 300 000 gal.; all of which is treated at purification works.

Character of Sewage. — Strictly domestic sewage, but diluted at times with more or less storm water.

Date of installation of plant, — 1899.

Stream receiving Effluent. — Dugway Brook; dry weather flow 2 or 3 cu. ft. per sec.

Method of Treatment. — Chemical precipitation. Precipitation tanks are 4 in number, each being 30 ft. square and 7 ft. deep. The total capacity is 160 000 gal. or 53 per cent. of the average daily flow. About 420 lbs. of lime are used each

day, this being mixed with the sewage during the daytime only. The sludge amounts to about 2.5 tons daily. It is pressed into cakes and deposited upon the ground adjacent to the plant, where large quantities of it are rapidly accumulating.

It was the original intention to treat the effluent from the chemical precipitation tanks in contact beds and then in sand filters. For this purpose two contact beds, each 64 by 127 ft., containing 2 ft. of coke breeze and 4 in. of gravel, together with 4 sand filters, each one-fourth of an acre in area and having 3 ft. of sand, were provided.

Results. — The chemical treatment, at least, is continued throughout the year. Owing to the extremely fine material (which, it is said, is due to lack of inspection at the time of construction) in the sand filters, it was found that they required much care, hence, the use of them has been abandoned.

Although the contact beds were provided with proper gates for holding the sewage in the beds, these gates have not been used and the sewage filters through continuously; the beds acting simply as strainers. The resulting effluent from the plant is not nitrified and has a musty odor; but it contains little suspended matter and produces little or no pollution in the stream which receives it. It is said that no complaints regarding odors have been made even by those living within 800 ft. of the plant.

Cost. — The cost of construction was $20 500 divided as follows: $6 000 for building and machinery, $4 500 for tanks and sludge well, $4 000 for filters. The cost of operation is about $2 300 every year, consisting of $1 320 for two attendants, $600 for lime, $380 for fuel and incidentals.

Kenton. (North District.)

Estimated population of entire city, — 8 000.

Estimated population using sewers which discharge at purification works, — 400.

Sewerage System. — The system which drains to the purification works, consists of a few miles of pipe sewers having about 75 house connections. Storm water from 1 or 2 catch basins is discharged into them.

Quantity of Sewage. — Estimated at 25 000 gal. per day.

Character of Sewage. — Domestic sewage diluted at times with more or less storm water. No manufacturing wastes.

Date of installation of plant, — 1901.

Stream receiving Effluent. — Artificial ditch.

Method of Treatment. — Septic tank followed by treatment in dosing filters and " wave beds," this being a modification of the Waring's forced aëration system.

The septic tank is 28 ft. by 16 ft. by 6 ft. holding 21 000 gal. or nearly 24 hr. flow. The dosing or " contact " filters are flush tanks, 3 in number, each 5 ft. by 10 ft. in area, and 2 ft. deep, and are filled with a mixture of charcoal, coke and pieces of limestone from 0.5 in. to 3 in. in diameter. These dosing filters receive the septic effluent continuously but are designed to discharge it intermittently through automatic siphons on to " wave beds."

The " wave beds " consist of 3 tanks 10 ft. wide and 100 ft. long, having a decided slope away from the dosing filters. They contain a layer of pea coke 18 in. deep at the upper end and 4 in. at the lower end, the coke being covered by a thin layer of broken stone.

The automatic siphon is designed to discharge the contents of a dosing filter into the upper end of the material in the wave beds, so that the sewage will quickly flow through the 100 ft. of material in the form of a " wave "; but without appearing at the surface of the material. This action is intended to produce thorough nitrification of the sewage.

Results. — The plant is kept in use at all times but the dosing filters at times become clogged and the automatic siphon is apt to discharge continuously on to the wave beds, and thus defeat the principle on which such beds are designed. Several samples of sewage and effluent have been analyzed and the results have been quite varied. The effluent at one time was well nitrified; but at another time, putrescible.

Cost. — The plant cost about $4 000 and the annual amount paid for maintenance is about $50.

Boys' Industrial School at Lancaster.

Estimated population, — 1 000.

Estimated population using sewers, — 1 000.

Sewerage System. — Sewers receive domestic wastes from all of the buildings, but no storm water.

Quantity of Sewage. — Average daily flow, 100 000 gal.; all treated.

Character of Sewage. — Strictly domestic. Large quantities of laundry wastes are discharged on certain days. As the water supply is obtained from deep wells, the temperature of the sewage is fairly high in winter.

Date of installation of plant, — 1899.

Stream receiving Effluent. — Small brook.

Method of Treatment. — Intermittent sand filtration, preceded by a simple screening of the sewage. The sand beds are 25 in number, all 43 ft. wide and varying in length from 60 to 100 ft., the total area being about 2 acres. The beds are located in a narrow ravine which necessitated their being placed in a row. The filtering material is 3.5 ft. in depth and is composed of excellent quality of sand which was obtained for the purpose by crushing sandstone, at a nearby quarry. One main underdrain passes through the centers of all 25 beds and each bed has three 4 in. lateral underdrains 10 ft. apart, leading into the center drain.

Results. — The plant produces, apparently, an excellent effluent at all times. The beds are well cared for, though the best possible distribution over the surface is not always obtained. It is said that, owing to the comparatively high temperature of the sewage, the sand does not freeze in winter although no precautions are taken against freezing. Objectionable odors are rarely if ever created.

Cost. — Cost of the plant was $8 900; cost of maintenance, if the value of the labor of the boys living at the institution is included, amounts to $25 or $30 per month.

Mansfield.

Estimated population, — 20 000.

Estimated population using sewers, — 10 000.

Sewerage system consists of 25 miles of sewers — 60 per cent. on the combined plan and 40 per cent. for domestic sewage only. Automatic overflow diverts a portion of the storm flows direct to creek. System includes inverted siphon 1 600 ft. long.

Quantity of Sewage. — Average amount treated at works, 1 000 000 gal. per day.

Character of Sewage. — Domestic sewage considerably diluted with ground water and, at times, with storm water. No manufacturing wastes.

Date of installation of plant, — 1902.

Stream receiving Effluent. — Rocky Fork; dry weather flow 1 to 3 cu. ft. per sec.

Method of Treatment. — Septic tanks followed by contact beds.

Portion of sewage discharges into pump well where it is

screened and then raised into septic tanks; remainder of sewage reaches septic tanks through inverted siphon. The pumping station also contains a garbage crematory.

Septic tanks are four in number, each 50 ft. by 100 ft. and 7 ft. deep, total capacity 1 000 000 gal. or 24 hr. flow. By means of an automatic, movable weir, a constant rate of discharge from the tanks is obtained. This causes a daily fluctuation in the elevation of the surface of the sewage of about 6 in. Effluent from septic tank is well aërated on its way to the contact beds.

The contact beds are 5 in number. Each is filled with 5 ft. of specially prepared cinders and has an area of .25 acres, making the total area 1.25 acres. The 5 beds form a circle, each being one sector. At the center of the circle is located the automatic controlling apparatus.

For short periods during heavy rains or during the flushing of sewers, the septic tank effluent is discharged directly into the creek.

Results. — During their 3 years of service, the septic tanks have accumulated only a few inches of solid matter at the bottom and practically no scum on the surface. The contact beds have not lost capacity to any noticeable extent and the effluent has been clear, practically odorless and non-putrescible. No objectionable odors have been caused by the plant. The automatic controlling device has given great satisfaction and the plant is kept in operation throughout the entire year except that occasionally, as noted above, the septic tank effluent passes directly to the creek.

Cost. — The cost of the plant was as follows:

Septic tank,	$17 700
Building,	12 500
Machinery (including crematory),	7 500
Filter beds,	18 800
Land,	6 650
Engineer's plans,	2 663
Superintendence of construction,	4 810
	$70 623

The cost of operation is about $4 000 per year including the cost of operating the garbage crematory. This amount includes the salaries of four men, fuel, supplies, etc.

MASSILLON STATE (INSANE) HOSPITAL.

Estimated population, — 1 000.

Estimated population using sewers, — 1 000.

Sewerage System. — Sewage from all the buildings is collected by a system of pipe sewers and conveyed through a 10-in. main to the storage reservoir, or flush tank.

Quantity of Sewage. — 100 000 gal. per day.

Character of Sewage. — Strictly domestic.

Date of installation of plant, — 1899.

Stream receiving Effluent. — Small tributary of Tuscarawas River.

Method of Treatment. — Intermittent sand filtration preceded by screening and storage in a flush tank. Broad irrigation used at times.

The storage reservoir or flush tank is 40 ft. by 15 ft. with an average depth of 5.5 ft.; capacity 25 000 gal. or 25 per cent. of the daily flow. Under the inlet to the tank is placed a basket screen.

The filter beds are four in number, each 100 ft. square, thus making a total area of about 1 acre. Each bed has 2 lines of 4 in. underdrains 50 ft. apart. The filtering material is 4.5 in. depth and consists of sand and gravel from a nearby bank.

Adjacent to the beds are about 20 acres of grass land upon which the sewage may be diverted when desired and disposed of by broad irrigation.

Results. — As far as can be learned no objectionable odors have been caused, and the plant is very successful both in winter and summer. Chemical analysis has shown the effluent to be well nitrified.

Cost. — The reservoir cost $1 055 and the filter beds $4 131. The plant is cared for by the patients at the institution.

OBERLIN.

Estimated population, — 5 000.

Estimated population using sewers, — 3 000.

Sewerage system consists of 10 miles of strictly domestic sewers having 650 connections. Storm sewers and special sewers for cellar drainage discharge directly into the creek.

Quantity of Sewage. — Average daily flow, 200 000 gal. All discharged at disposal works.

Character of Sewage. — Strictly domestic.

Date of installation of plant, — 1894.

Stream receiving Effluent. — Plum Creek; small intermittent stream, tributary to Black River.

Method of Treatment. — Broad irrigation, intermittent filtration and chemical precipitation.

The disposal area contains 1.75 acres ditched (but not underdrained) for broad irrigation and 3.5 acres of beds designed for intermittent filtration. The filtering material is simply the natural sandy loam which covers the area. This material was not moved except where necessary in grading and underdraining the filter beds. A rough pit was used as a settling basin (later as a septic tank) in which to retain the sewage for a short while before applying it to the land.

From 1894 to about 1900, the works, as just described, successfully purified all the sewage of the village (amounting to 100 000 gal. per day or less). As the amount of sewage increased, however, the filter beds as well as the broad irrigation area became clogged so that the sewage overflowed into the creek.

In order to avoid grossly polluting the creek, it was decided to transform the filter beds into precipitation tanks. Accordingly in the summers of 1902 and 1903, at which times the flow was about 200 000 gal. per day, sulphate of alumina or alum, at the rate of 100 lb. per day was introduced into the sewage by means of an automatic device located in a manhole on the trunk sewer.

In the summer of 1904, owing to the fact that the public water supply was being softened by a newly installed softening plant, the character of the sewage became such that lime and sulphate of iron (or copperas) in economical quantities was found to be effective in clarifying the sewage; whereas, previous to the installation of the water softening plant the quantity of chemicals necessary to produce clarification would have made their use too expensive.

About 125 lb. of copperas and 150 lb. of lime are, therefore, daily mixed with the sewage during the warmer nine months of the year. The copperas is introduced into a lateral sewer, near the upper end of the system, at the softening plant; while the lime is introduced at a point nearer the outfall.

Results. — The works as originally laid out (about five acres prepared to receive sewage) proved to be entirely too small to treat more than 100 000 gal. of sewage per day.

The use of alum, or copperas and lime, as above described, is said to have prevented gross pollution of the creek. During

cold weather, however, the untreated sewage has been allowed to discharge directly into the stream.

The odors arising from this disposal area have caused complaint on the part of persons living some 1 000 ft. away.

Cost. — The original cost was $2 490, of which $1 500 was paid for the land. The annual cost of maintenance is $250. At first this was paid for labor, but more recently it has been used chiefly for chemicals.

The Columbus Sewage Testing Station.

At the present time, the most interesting feature in the subject of sewage purification in Ohio is the Sewage Testing Station at Columbus. But as accounts of this station have already been published in the "Engineering News," "Engineering Record" and Ohio "Sanitary Bulletin," and as a complete published report of the work at the station is expected later, from the city officials, I will simply make a brief statement concerning it.

The citizens of Columbus, having voted, in the fall of 1903, to spend $1 200 000 in improving the city's sewerage system and purifying the sewage, it was decided to spend $46 000, or about 5 per cent. of the total amount, in determining the best and cheapest method of sewage purification for Columbus, under Columbus conditions as regards character of sewage, design of sewer system, topography, available materials and degree of purification required. Accordingly, the Sewage Testing Station with its corps of 14 trained engineers, chemists and bacteriologists was established in the early part of 1904 and put in operation in August. The tests will cover a period of one year. Some 45 experimental tanks and filters of different types and containing all kinds of materials have been constructed with these devices, all practical methods of sewage purification will be tested and the character of Columbus sewage studied. The results of these tests and observations will serve as a basis of design for the future works.

In making these preliminary tests, the Columbus officials are certainly solving the problem in a broad and rational way, and it is to be hoped that other cities, when necessary, will make correspondingly thorough examinations into local conditions and best methods.

A WINTER VISIT TO SOME SEWAGE DISPOSAL PLANTS IN OHIO, WISCONSIN AND ILLINOIS.

By C.-E. A. Winslow, Member of the Boston Society of Civil Engineers.

[Read before the Sanitary Section of the Society, April 5, 1905.]

We must go west in order to learn the new things in sewage purification. In New England the classic Lawrence experiments of 1890 have firmly grounded our theory, and the mantle of glacial drift makes our practice easy. Beyond the range of the Appalachians all is changed. The character of sewages and the available materials for treating them are alike different. Old England rather than New England furnishes comparable conditions and we find a general development of the newer British processes through the Mississippi Valley. Even these methods, however, prove not wholly suited to their new conditions. Many of them are failures, on account of climate, on account of varying sewages, on account of the political conditions which make it difficult to secure efficient public service in American municipalities. No saying, however, is more true than that "We learn by making mistakes." They are learning a great deal in Ohio and Wisconsin and Illinois about the rapid methods of sewage purification. Columbus is doing for such processes what Lawrence did for sand filtration fifteen years ago. The whole region is an inspiring one for the sanitarian to visit.

In a short trip through the Middle West during January of the present year I had the opportunity of seeing some dozen sewage purification plants of various types under the most unfavorable conditions of practical operation, and I have been asked to tell you what I saw, in the hope that even such a fragmentary report may help us to estimate the success of the newer processes of sewage treatment in this country and their promise for the future.

From the admirable report by R. W. Pratt on Ohio sewage plants in 1903 it appears that there were then eleven sand filter plants in the state of Ohio, with which no sort of preliminary treatment was used. One was a subsurface system; one was wholly, and two were partly, given up to broad irrigation. All but three were small plants serving institutions, and the total population connected with the eleven plants was only 21 000. One of the best of these intermittent filters is that at the Ohio State

Reformatory at Mansfield, O. (Pratt, 1905). The sewage from a population of six or seven hundred persons, amounting to 60 000 to 70 000 gal. per day, is discharged on seven small beds with a total area of 1.1 acres. The beds are built of friable sandstone taken from a cliff near by and crushed by the prisoners. The effluent is said by the engineer of the State Board of Health to be of good quality, but considerable trouble has been experienced in keeping the beds clear in winter. They were originally plowed with deep furrows 1.5 ft. high, and 4 ft. apart, but this worked badly, as the available area was unduly decreased and the beds froze. At the time of my visit small furrows 6 in. high were giving poor results, the beds being half frozen and covered with slush. Probably a judicious mean might prove more favorable.

The only other intermittent filtration plant I saw in the West illustrated the difficulties which attend this process where ample areas of sand cannot be obtained. Oberlin, O. (Pratt, 1905), is a village of 5 000 inhabitants lying 30 miles west of the city of Cleveland and 10 miles from the shore of Lake Erie. The first sewers were constructed in 1892 and two years later a field in the outskirts of the town was laid out for sewage disposal. Six acres of fine sandy loam were available to receive gravity flow, of which three acres and a half were underdrained for intermittent filtration and an acre and three quarters merely ditched for broad irrigation. Two settling basins, 3 ft. deep and 10 ft. by 30 ft. in area, were constructed by excavating pits and boarding up the sides, and from these the sewage overflowed through distributing ditches on the beds. Sludge from the pits was pumped out and dumped near by; it amounted to some 4 per cent. of the sewage treated. For some years the plant worked well while the average flow of sewage remained below 100 000 gal. per day. Since 1902, however, it has rapidly increased, to some 250 000 gallons at the present time, and the beds have become heavily overtaxed. In order to prevent serious pollution of the creek below, the system has been converted into a sort of chemical precipitation plant by a process probably unique in the history of sewage purification. During the warmer nine months of the year chemicals are discharged into the main sewer of the town, about 125 lb. of ferrous sulphate and 150 lb. of lime in the form of hydrate, by automatic devices located respectively at the upper end and the middle of the system; sedimentation takes place in the pits and on the beds which are generally clogged and a considerable

nuisance is created. At the time of my visit in January no chemicals were being used and the sewage was simply standing on the beds and overflowing into the creek, turning the whole area into a noxious swamp.

The reason for the failure of this Oberlin plant is, of course, the absence of a sufficient area of land really suitable for intermittent filtration. In this respect it is fairly typical of general conditions throughout the Middle West. Sand treatment alone is inadequate over most of this great region; and it has been necessary to seek some preliminary process which should make possible filtration at more rapid rates. As in England, chemical treatment first suggested itself for this purpose and a number of plants have been installed, somewhat less crude than the one just described. Glenville, O., has chemical treatment preparatory to passage through the contact bed, and at Alliance, O. (9 500 population), and Canton, O. (32 000 population), chemical precipitation is the only method used. Both the latter plants are said to be well operated and to yield fairly satisfactory results (Pratt, 1905).

As in other localities, however, the disadvantages of the chemical treatment have been made manifest. Poor effluents, offensive sludge and costly operation prove almost inseparable from this method. It was natural, therefore, that engineers should turn their attention to some better method for removing suspended solids. It soon appeared that such a method could be developed by the regulation of the anaërobic ripening process which goes on in every cesspool. Such a preliminary ripening liquefies a considerable portion of the solid material in sewage. According to its advocates it does the work of chemical precipitation without the cost of chemicals and with a diminution of objectionable sludge. As championed by Donald Cameron of Exeter, who gave it the picturesque name of "septic tank," this anaërobic process seemed most promising; and nowhere has it been more cordially received than in the Middle West. Indeed, there may almost be said to be a cult of the septic tank in Illinois and Wisconsin. Even in small towns where no system of sewage purification is really essential the possession of a septic tank is a matter of municipal pride; in some half dozen towns this is the only method of treatment, the clarified effluent being discharged into the nearest body of water without any attempt at nitrification.

I saw one such system at Highland Park, a lake shore suburb of Chicago with a population of about 4 000. Two-thirds of the

village drains westward and the sewage from this region has been treated for some years by the septic tank method. The new tank which I saw in operation was put in by W. S. Shields only three months ago, and takes a portion of the sewage from the eastern part of the village along the lake front. Two other outlets from this region discharge into the lake without treatment. The tank is covered and underground and in somewhat close proximity to the pumping station of the waterworks. At the time of my visit its effluent contained considerable suspended matter, but as the tank had been in operation for so short a time and during cold weather it could not have attained its normal condition. With regard to the wisdom of treating sewage by the septic tank alone without a subsequent aërobic process, I must confess myself somewhat skeptical. There may be cases where raw sewage would cause a nuisance, while the clarified septic effluent is sufficiently improved to do no harm; but such a balance of conditions must be rare.

In general, of course, the septic tank treatment is only used as a preliminary to intermittent or contact filtration, and on these principles many admirable plants have been constructed and are in operation in the Middle West. Of the first type I saw three good examples, one at Lake Forest, Ill., and two at Wauwatosa, Wis. The Lake Forest plant was designed in 1902 by J. W. Alvord and W. S. Shields (Alvord, —) to care for a flow of 350 000 gal. a day. A population of 1 800 at that time has now increased to about 3 000, and it is probable that the plant is nearing its full capacity. It is beautifully located at the bottom of a bluff on the shore of Lake Michigan. The sewage first flows through an open brick septic tank protected from abrupt temperature changes by a light brick structure and divided into five compartments so arranged that by various combinations the period of septic action may be adjusted to suit varying conditions. (Fig. 1.) Mr. Alvord has pointed out the desirability of so building tanks that the period of fermentation may be altered with changes in temperature and in the volume and composition of the sewage; and most of his recent septic plants are built upon this principle. The theory, upon which this practice rests, is that a too brief period fails to remove a maximum of solid material while over-prolonged septic action produces an effluent which is for some reason hard to nitrify. It is, unfortunately, almost impossible to secure proper expert supervision of sewage disposal under present conditions, and at all the plants which I visited the operation of the " elastic tank " had been

practically abandoned and the whole available area was used as a single tank.

At Lake Forest with a tank 35 ft. by 20 ft. in area and 8 ft. deep, and a capacity of 50 000 gal., this method of operation gave a period of about four hours. One third of the tank back of the first baffles was covered with a very heavy layer of frozen scum while the rest of the tank showed only half an inch of light scum. The effluent from the tank which runs over an aerating weir into a dosing chamber of 7 000 gal. capacity, appeared to be a good septic sewage, dark colored and with only very fine suspended particles. The tank has never been cleaned out.

One important feature of the western sewage plants is the general attempt to introduce automatic devices for regulating flow and for dosing filter beds. The danger from the failure of such devices is, of course, always considerable and they absolutely require periodic expert supervision; but by and large I am inclined to think even a fair automatic device will prove as reliable as the average city employee. The apparatus used at Lake Forest for dosing the sand filters is an extremely ingenious one. A float in the dosing chambers lifts a cannon ball in one of a set of hollow wooden columns arranged in series, and at a certain height the ball rolls through a trough from one column to the next, in its passage striking a catch which opens an air valve attached to one of ten bell syphons in the dosing chamber. Each syphon discharges on one of the ten sand filters which may thus be dosed in rotation. At the time of my visit the automatic device had been purposely thrown out of gear so that the sewage was flowing continuously upon one bed, perhaps with the idea of preventing the surface from freezing.

The sand filters are each 3 200 sq. ft. in area, the total area being three-fourths of an acre and the rate is therefore now over 400 000 gal. per acre per day. The filtering material, the natural beach sand of Lake Michigan, is quite fine, 85 per cent. passing a sieve with 40 meshes to the inch, and 42 per cent. passing a sieve with 60 meshes to the inch. The distributing carriers used here and elsewhere by Messrs. Alvord and Shields struck me as admirable, — for small beds superior, perhaps, to those which are more common in the East. They are straight or branched troughs made of two upright sides of 2 in. plank, resting on a similar bottom plank with 3 in. square holes at the base of the sides, spaced about 2 ft. apart. Like all distributing devices their operation requires sufficient head to yield a

good gush of sewage; given this they should be perfectly satisfactory.

With the dosing device deliberately thrown out of operation, as I have mentioned, the Lake Forest plant was not doing wholly satisfactory work. Sewage was standing several inches deep on the one bed which could receive it, and the effluent as it flowed off to the lake was dark colored and appeared imperfectly purified.

A plant very similar to that at Lake Forest was built four years ago by Alvord and Shields for the town of Wauwatosa, Wis. (Alvord, —). The population of the town is about 3 000, but there are not more than 200 connections with the sewer system, including a sanatorium, a pickle factory and a chemical works. The flow is said to be about 100 000 gal. a day. The sewage first enters a concrete septic tank sheltered as at Lake Forest by a brick roof. The tank is approximately 15 ft. by 50 ft. by 10 ft. deep with a capacity of 40 000 gal. It was originally provided with three longitudinal partitions but the sewage is now run straight through, giving a storage period of 10 hr. At the time of my visit the first tenth of the tank behind the first baffle bore 6 in. to 8 in. of very heavy scum, and a considerable accumulation of sediment could be felt at the bottom. The town engineer informed me that the tank must be cleaned out twice a year, a quantity of combined scum and sludge equal to half its capacity being removed by dipping out with pails and by the use of a small rotary pump. The effluent appeared like a good septic sewage, dark gray in color and with no large particles.

The septic effluent should pass to a dosing chamber in a separate small brick structure where it may be discharged on sand beds by the same device in use at Lake Forest. (Fig. 3.) The beds are 6 in number, 30 ft. by 60 ft., with a combined area of one-fourth acre, thus giving a rate of 400 000 gal. The sand used is coarse and the results obtained are said to be excellent. In cold weather, however, it is the practice of the authorities to discharge the septic effluent directly into Menominee Creek without filtration. This has not been compelled by any failure of the plant, but is done to avoid the expense of caring for the surface of the beds during a season when the septic tank effluent will not produce a serious nuisance in the river below. Like the use of storm overflows such a custom does not commend itself to the sanitarian; but from the standpoint of the city engineer it may be good economy.

In the same town is a larger plant of almost exactly similar construction (Shields, 1904), which shows what good results can be obtained by careful and efficient operation. The Wauwatosa County Institutions form a group of five buildings, including two insane hospitals, an almshouse, a county hospital and a home for dependent children. The total population is about 35 00 and the water consumption, 400 000 gal. per day. A chemical precipitation system was put in in 1888, the dosing house and coagulating basin still remaining as its monument. Then a septic tank alone was installed; but it proved unsatisfactory, and about a year ago Mr. Shields built a new septic tank and filter beds. It is planned to use the old tank as a part of the septic system in the future, but at the time of my visit the sewage was flowing only through the newer one. This is 85 ft. long, 20 ft. wide and 8 ft. deep with a central longitudinal partition and 3 concrete baffles. The first two compartments, making up about a third of the tank, bore a thick frozen scum raised by gas pressure 6 in. above the surface of the liquid. At the outlet as it ran off over an aërating weir, the effluent appeared a strong septic sewage still containing a fair amount of suspended matter. The storage period under present conditions appears to be 6 hr. With the addition of the old septic tank, 8 ft. by 17 ft. by 54 ft., it would be increased to 9 hr. Both tanks are of concrete, housed under low brick buildings with gabled roofs.

From the septic tank the sewage flows through an inverted siphon to the filter beds which are located on the further side of a small stream. The beds are eight in number, arranged in two rows with a controlling house in the centre. (Fig. 2.) The four corner beds are each 50 ft. by 110 ft. while the four centre beds are 57.3 ft. by 55 ft., being shortened to provide room for the distribution system. The latter is of the general pattern described above, including a dosing chamber discharged by any one of eight 15-in. syphons, each connected with one bed. The rotation of the beds is controlled automatically by a cannon ball device quite similar to that used at Lake Forest.

The filter beds are built up of 12 in. of coarse gravel, 12 in. of fine gravel and 12 in. of coarse sand, and are underdrained by four lines of 4-in. pipe. The carriers are of the usual type, two straight troughs in each bed with 3-in. square holes about 2 ft. apart.

The plant is carefully supervised by the superintendent of the institution, and was working in admirable shape when I

saw it. The siphons flush perhaps once every 35 min. in the morning, every 45 min. in the afternoon, and once an hour at night, so that each bed is dosed once in from 4 to 8 hrs. The total area is about 1 acre for the 400 000 gal. treated.

In spite of severe weather in January the dose disappeared in twenty minutes after its application; but at intervals it is necessary to rest a bed for a few days by putting into the cannon ball regulator a chute which shall shut out one of the dosing siphons. The effluent from the plant as I saw it flowing into the Menominee Creek was clear and well purified.

It is only rarely that such plants as those at Wauwatosa can be installed in the West, for the use of larger communities, since, even after preliminary septic treatment, the requisite sand area is generally unobtainable. Hence, the newer English types of filters have been frequently adopted; and we find the septic tank and contact filter the most popular of all combinations through Ohio and Iowa. A dozen systems of this type are installed in these states, with an aggregate contributing population of 60 000. Mansfield, O. (20 000), Marshalltown, Ia. (11 000), Delaware, O., and Kenton, O. (each 8 000), are the largest cities in this class.

The disposal system at Mansfield (Pratt, 1905), built by Snow and Barbour, three years ago, is one of the most perfect of this type as well as the largest. The town is a thriving farming and manufacturing centre with a population of 20 000. About half the inhabitants contribute sewage, the total amounting to 1 000 000 gal. per day. The purification works, about three-fourths mile from the centre of the city, and with dwellings not an eighth of a mile away, is as neat as a pin, from its well-kept driveways and embankments to the spotless engine room with a row of potted plants in the window. The sewage flows by gravity to a sludge well from which it is raised by two 7-in. centrifugal pumps to the septic tanks. Both tanks and sludge well are ventilated by connection with the stack from a Dixon crematory in the pumping station which handles the city garbage, amounting to 15 to 20 tons a day.

The septic tank is an arched concrete chamber covered by an artificial mound, its presence being indicated only by the manhole covers. It is built in four compartments, each 50 ft. by 100 ft. and 7 ft. deep with a total capacity for the four of 1 000 000 gal. The sewage flows now through all in parallel, the period of septic action being twenty-four hours. In the three years of their operation these tanks have never been

cleaned and the superintendent informed me that not more than 1 in. of sediment and 2 in. of light scum have ever formed. Comparison with some of the tanks described above suggest that perhaps the longer period of septic action has had some share in these excellent results.

From the septic tanks the sewage flows over a series of aërating steps (Fig. 4), and thence to the regulator house situated in the center of a circular group of five contact beds. The automatic dosing device, consists of two concentric iron cylinders about 2 ft. in diameter, the outer one stationary and pierced by five ports, one for each bed, the inner one revolving so as to bring its single influent port successively opposite each of these five points of discharge. A float, regulated by the height of sewage in whichever bed is filling, at a certain height starts the inner cylinder, closes the outlet from the bed next to be filled and opens the outlet of the bed which has stood full since the last revolution. Each of the beds has an area of one-fourth acre and is filled with one-eighth in. to one-half in. cinders to a depth of 5 ft. The period of contact is about 4½ hr. and the rate of treatment 800 000 gal. per acre per day.

At the time of my visit the beds had been out of use for two or three days during the process of cleaning out part of the low level sewer system, as it was feared the silt might damage them. The septic effluent was going straight to the nearby stream. I was informed by the superintendent that this had occurred only once or twice before during the operation of the plant. The surface of the beds seemed in admirable condition and the effluent of the plant, according to the analysis published by Pratt (1905), is generally excellent.

I was somewhat unfortunate in my experience with contact beds during my trip. Of five plants of this type, that at Mansfield was temporarily out of operation on account of what seem to me quite legitimate reasons. In two others the automatic dosing devices were so frozen up that the beds were not being dosed at all; and a fourth had been entirely abandoned as a nuisance. Only one, that at East Cleveland (Pratt, 1905), was running properly; and this plant is of so peculiar a type that it can hardly be said to operate on the contact plan at all. The flow through three successive rows of slag beds is continuous for a period of several days, air being supplied by forced aëration on the Waring plan; but perhaps this plant may be considered more nearly allied to the contact bed than to any other system.

East Cleveland is a town of 6 000 inhabitants lying near the

shore of Lake Erie, just east of the city of Cleveland. The larger part of this population contributes sewage, the total amounting to some 400 000 gal. It is said that this amount is trebled by leakage and surface drainage at certain times of year. At the disposal area the sewage flows first to an open receiving well where a considerable amount of solid matter settles out, the accumulated sludge being pumped out twice a week, mixed with lime and dumped on land near by. The supernatant sewage is pumped from the well to a septic tank, 87 ft. by 24 ft. and 11 ft. deep, covered by a wooden pitched roof. The period of septic action is 10 hr. or less. Pratt (1905) states that after a year's operation about a foot of sludge was taken from this tank. At the time of my visit a heavy cheesy scum, 6 in. in thickness, covered the whole tank and the effluent was markedly turbid. It may be that the period of septic action is too short or that the storm water brings in material not easy to handle; but certainly this tank seems much less successful than others. No problem in sewage disposal is more puzzling than the question why one septic tank succeeds and another fails. Mr. Alvord (1902) strongly maintains that tanks which are too large as well as tanks which are too small tend to fill up, and considers 4 to 8 hr. a proper fermentation period. Shields (1904), on the other hand, recommends that septic tanks should have a capacity of not less than three-fourths of the daily flow.

Certain English experiments seem to indicate that a variation from 12 to 48 hr. makes little difference. It is *a priori* difficult to understand why long periods of septic action should increase sludge deposits. If flow is so rapid that solid particles have not time to settle out or if accumulation of sludge goes on faster than its dissolution, bad results may follow. But with slow flows the processes of liquefaction should have the best chance to do their maximum work, and sludge ought not to accumulate; although here the possibility must be recognized of septic changes in the sewage itself which may be inimical to bacterial action in later processes.

From the septic tank the sewage at East Cleveland flows through three sets of beds filled with 2.5 ft. of coarse slag, of egg-coal size, passing downward through the first, upward through the second and downward through the third. Air is forced into the spaces under each bed by aërators shown in the figure. (Fig. 5.) With the aid of this aëration it was hoped that some of the organic matter could be nitrified and the rest strained out by the slag and finally oxidized by allowing the

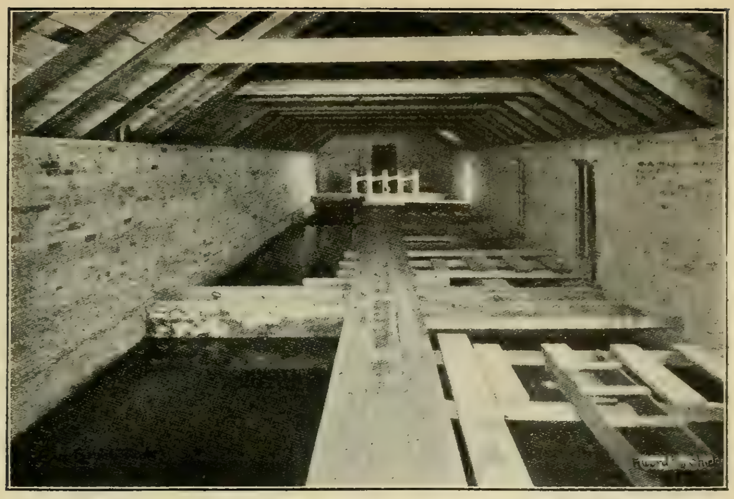

FIG. 1. INTERIOR OF SEPTIC TANK AT LAKE FOREST. IN FOREGROUND LATERAL TROUGH FOR COMBINING VARIOUS COMPARTMENTS. IN BACKGROUND AUTOMATIC DIVERSION CHAMBER.
(After Alvord.)

FIG. 2. SAND BEDS AND REGULATOR HOUSE, WAUWATOSA COUNTY INSTITUTIONS.

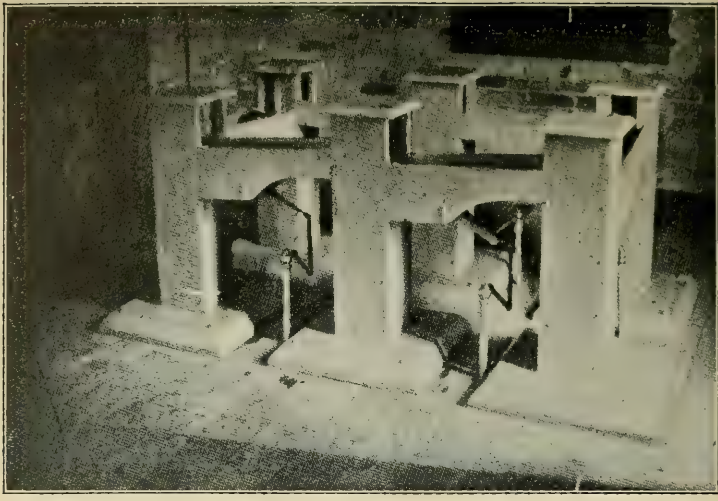

Fig. 3. Automatic Ball-Controlled Device Operating Six Intermittent Filtration Beds at Wauwatosa, Wis. View taken Four Minutes after Discharge in Diversion Chamber. Dose, 6 000 Gal.
(After Alvord.)

Fig. 4. Mansfield Aerating Device.

FIG. 5. EAST CLEVELAND PUMPING STATION, WITH RUNWAY FOR SLUDGE FROM WELL, SEPTIC TANK HOUSE (ON RIGHT), AND FILTERS OF STONE WITH AERATING DEVICES.

FIG. 6. FIRST AND SECOND CONTACT BEDS AND REGULATOR HOUSES AT GLENCOE.

FIG. 7. FIRST AND SECOND CONTACT BEDS, WITH SEPTIC TANK IN BACKGROUND AT LEFT, AT WESTERVILLE.

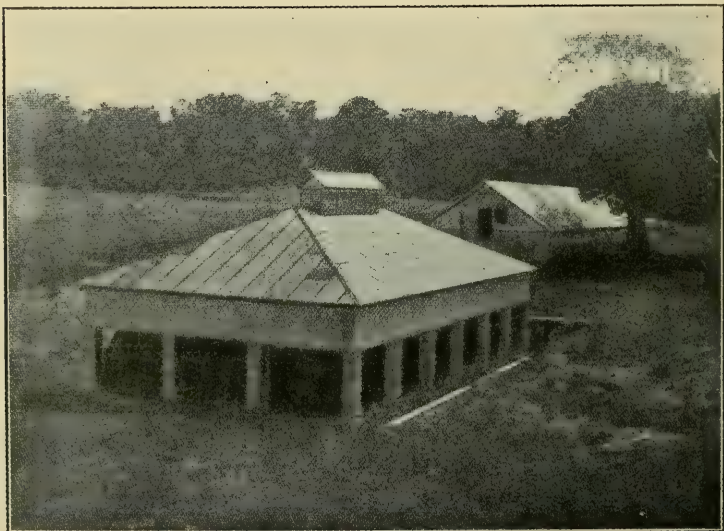

FIG. 8. WEST ALLIS AËROBIC FILTER.

(After Shields.)

beds to stand empty for a period at frequent intervals. At present each filter is run for three days and then rested for the same period. The plant is said to give good results in summer, but at the time of my visit it was noticeably offensive in odor, and the effluent was turbid and imperfectly purified. The use of forced aëration seems a doubtful expedient in sewage purification when one considers the large amount of oxygen consumed by sewage in a trickling filter, for example, and the impossibility of supplying such an amount by any practicable mechanical system. The use of the beds for continuous three-day periods also seems unwise. The total filter area of half an acre, if laid out in contact beds somewhat deeper than those now in use and operated in the usual manner, should be able easily to handle the flow of 400 000 gal. daily.

A short distance north of the East Cleveland plant a smaller contact system is installed at the Lake Shore & Michigan Southern Railroad Car Shops in the thickly settled portion of the village of Collinwood (Pratt, 1905). The sewage of 500 operatives flows to a pump well from which it is automatically raised at intervals by a pump driven by compressed air and discharged into two septic tanks, each 21 ft. by 10 ft. by 9 ft. deep, with a capacity of 25 000 gal. When the sewage in the septic tanks reaches a height of 8 ft. they are supposed automatically to discharge the upper 2.5 ft. into four contact beds, concrete basins, each 15 ft. by 29 ft., filled with 5 ft. of 2-in. limestone. On filling, the beds discharge through siphons. The plant is a neat and compact structure with brick walls and plank covering and is supposed to operate entirely without supervision. At the time of my visit all the automatic devices were frozen, the pump was not working, the septic tank contained a thin but foul stagnant liquor and the sewage was apparently flowing off through a by-pass. Such must infallibly prove the fate of automatic devices if their automaticity is construed literally and they are left entirely without supervision.

The fourth contact filter which I visited was at Glencoe, Ill., a suburb of Chicago lying on the northern lake shore between Highland Park and Evanston. It has a population of 1 500, about two-thirds contributing sewage to the system. The Cameron Septic Tank Co., installed a plant some three years ago consisting of a septic tank and double contact beds. Like that at Lake Forest it is located on the shore of the lake and hidden from the town by a high bluff, but in general appearance

the plant is sufficiently attractive to be displayed rather than hidden. It consists of a covered concrete tank some 80 ft. long and 10 ft. wide, a set of four primary contact beds with a combined area of about 1 200 sq. ft. and a similar battery of secondary contact beds at a level about 4 ft. lower. On the lower beds are two neat brick regulator houses which contain a complex arrangement of floats and cranks for the automatic control of the beds. (Fig. 6.) The material in the beds is said to be slag, but on the half frozen surface there seemed to be a considerable admixture of rather fine gravel and cinders. According to the City Clerk, the plant worked well for a time, but gradually became a nuisance to the neighborhood, being offensive all through 1904. Last fall the beds became so clogged as to overflow continuously and the plant was abandoned, the sewage being discharged directly into the lake.

I am inclined to think that the conditions in these last two plants are due to difficulties inherent in the contact system of sewage purification as applied to small plants. The process is a complex one involving successive aërobic and anaërobic fermentations which must be delicately adjusted. With the lack of supervision which is almost inevitable in a small disposal system, automatic devices will fail and filters will be thrown out of operation or overdosed so as to cause clogging. The slow sand filter and the trickling filter, being simpler in theory and easier of regulation in practice, are much better fitted for installations liable to be left to themselves for days and weeks at a time.

A plant with a sufficient excess of capacity may, of course, give fair results even when neglected; and a good example of this is furnished by the system at Westerville, O. This village, a few miles northwest of Columbus, has 1 500 inhabitants but not more than 100 persons are connected. The daily flow is from 20 000 to 25 000 gal. and includes the waste from a creamery, which introduces a large amount of refractory organic matter from the washings of the cans. The sewage first flows through a pair of septic tanks, each 8 ft. by 26 ft. in area and 8 ft. deep, with a combined capacity of about one day's flow. The tanks are of concrete, covered with planking, and appear to do good work, the sewage as it enters being strong and turbid, the effluent clear and free from suspended matters. On leaving the tank the effluent passes through an aërating chamber in which it flows over three iron discs of successively increasing size, the lowest being 2 ft. 6 in. in diameter. It is then passed through

six primary contact beds, each with an effective area of 0.021 acre, containing 3 ft. of screened cinders, one-eighth in. to 1 in. in diameter, and finally through two secondary filters, each 13 ft. sq. at the bottom and 31 ft. sq. at the top, containing 6 ft. of cinders. (Fig. 7.) The primary beds are dosed by two devices, each of which consists of a perforated bowl resting ball-and-socket fashion in an upright influent pipe and overflowing through three trough-like arms to the various beds. At the time of my visit the devices were out of order and the sewage was trickling continuously on four of the beds, forming a pool on the surface 6 ft. in diameter which an abundant growth of Leptomitus shows to be fairly permanent. Pratt (1905) in his description of these beds notes the same conditions. The primary beds should be discharged on the secondary beds by siphons, each one operated by the height of sewage in the adjoining bed. These devices too were inoperative and sewage was steadily dribbling on, so that both sets of beds were working like trickling filters, but, of course, with the most incomplete sort of distribution. The pools on the upper filters were somewhat offensive and the odor of the plant was noticeable several hundred feet away. The effluent standing on the secondary beds was much less disagreeable and the final effluent below the plant, clear and odorless. With such a low rate of filtration (200 000 gal. per acre per day on each set of beds), even this neglected system was yielding fair results.

In actual operation the Westerville plant was acting like an imperfect sort of trickling filter; but there are *bona fide* systems of this type in the Western States which are of very special interest. The largest trickling filter, I believe, is the one which handles the sewage of the 20 000 people of Madison. I did not see this, but I found a smaller plant installed at the car-shops of the Allis-Chalmers Co. at West Allis, just out of Milwaukee. This plant, designed by Mr. Shields in 1902 to care for 80 000 gal. of sewage per day from the large factory in which 3 500 men are employed, is located on a hillside behind the works and consists of a concrete septic tank and anaërobic filter covered with a gabled roof and a trickling filter under a second roof and at a lower level. The open septic tank is divided by a central partition into two long tanks, each 10 ft. by 58 ft. and 7.5 ft. deep, the total capacity being 65 000 gal. or 18 hr. flow. Below the tank the sewage is aërated by fall over a weir and some steps and then enters the anaërobic filter, so called, which is practically a second septic tank, 21 ft. by 33 ft. long and 7.5 ft. deep, filled with clinker and cinders in graded layers. After

flowing upward through this tank the sewage passes to three 3 ft. by 5 ft. siphon chambers which discharge it on the trickling filter below. This filter is practically a pile of cinders and clinker, varying from 0.25 in. to 0.75 in. in diameter held together by larger clinkers on the outside, piled with a slight batter. The height of the heap is 7.5 ft. to 8 ft., its superficial area, 30 ft. by 54 ft., and the concrete floor upon which it rests is 40 ft. by 60 ft. Considerable trouble has been experienced from disintegration of the clinkers. In winter, as I saw it, the sides of the filter were closed in by plank walls; but in warm weather the whole is open. (Fig. 8.) The distribution system is very simple, consisting of three 12 in. plank troughs with 4 in. lateral troughs in the bottom of which 0.25 in. slits are cut at a distance of 8 in. apart. Each siphon discharge floods one main trough with its laterals, and the distribution as I saw it appeared satisfactory.

The general design of this plant seems admirable, the only part of it to which I should take serious exception being the anaërobic filter. According to the designer (Shields, 1904) its object is "to produce conditions under which the facultative bacteria can do their work and prepare the effluent for more rapid nitrification in the aërobic filter." An action of this sort is very hypothetical. We have little proof that septic action favors subsequent nitrification aside from the removal of suspended solids and some evidence that if prolonged it may seriously hinder it. Furthermore, filling up a septic tank with stone makes the difficulty of cleaning so serious that the extra straining capacity is dearly bought.

Mr. Shields states that the actual flow of sewage at the plant has been much greater than that for which it was designed, reaching a rate of over 300 000 gal. per 24 hr. for 12 hr. of the day. No trouble has been experienced from freezing, and the trickling filter has been operated at a rate of over 3 000 000 gal. per acre per day, yielding a bright and odorless effluent. It appeared evident, however, on my visit that the applied sewage is of unusual character, being mainly clear wash water from boilers and manufacturing processes with fragments of fecal matter floating in it only here and there. Furthermore, its temperature is raised by the spent steam to 70° and over at times. In the trickling filter house the air was wet and steamy but without any of the offensive odor of ordinary sewage.

For results of general significance on the applicability of trickling filters we must turn to the Columbus experiments. We are all familiar with the inception of these most important

Fig. 9. Columbus Testing Station. Sprinkling Filter.

Fig. 10. Columbus Testing Station. Filter House with Laboratory Beyond.

investigations. In the fall of 1903 the city appropriated $1-200 000 for the improvement of its sewerage system and the purification of its sewage, and the authorities were sufficiently far-sighted to devote $46 000 of the money to a preliminary study of the methods of disposal best suited to the local conditions. An admirable experiment station was designed and a corps of fourteen experts under the direction of Messrs. Hering and Fuller began work Aug. 16, 1904. It includes a laboratory, one set of open tanks for preliminary treatment and three sets of filters, with a gallery under a frame covering, for each set. (Fig. 10.) The sewage, amounting to some 350 000 gal. per day, is raised by a centrifugal pump to a screen chamber in which it passes through two movable screens of three-eighths in. diagonal wire mesh. Next it passes to one of the tanks for preliminary treatment. These are seven in number, each 40 ft. by 8 ft. and 8 ft. deep at the upper end and 9 ft. deep at the lower end, built of wood lined with galvanized iron. The first two tanks are called grit chambers, the sewage flowing through in about 1.5 hr., and these tanks are used as a preliminary to all the other processes. The other five tanks are either "plain sedimentation" or septic tanks, in which the sewage remains 8 hr. or more, the difference being that the former are emptied and cleaned whenever septic action begins, while the latter have not so far been cleaned. In the septic tanks periods of 8, 16 and 24 hr. are under comparison.

The sewage after treatment by one of these three preliminary processes (grit chamber, plain sedimentation basin or septic tank) is finally purified by treatment in one or more of thirty-five experimental filters. These are cypress tanks 6 ft. deep; one is 10 ft. in diameter, four 12 ft. 10.75 in. in diameter and thirty 7.5 ft. in diameter. They are all open filters and arranged for the most part in two blocks of two rows each with a covered dosing and sampling gallery between the rows, in which all the engineering details of operation are regulated with the greatest accuracy. Twenty-one are intermittent sand filters, 2 primary and 4 secondary contact beds of broken limestone, 2 coke strainers and 5 trickling filters. With this splendid plant the widest possible series of combinations can be tried, including sand filters, trickling filters and contact beds alone, either of these preceded by plain sedimentation or septic treatment and sand filters preceded by contact or trickling filters.

One of the most striking points about this plant is the

considerable amount of solid matter which it has been found necessary to remove. First, the sewage is screened where it is pumped out from the sewer; next it passes through two screens of three-eighths in. mesh in the screen chamber; next it settles for an hour and a half in the grit chambers. All the sewage without exception is purified to this extent before its regular treatment begins. I was told that in the sedimentation tanks 2.5 tons of sludge collected per million gallons of sewage treated, while in the septic tanks only half this amount had accumulated with no surface scum. In the second place I was struck with the marked success of the aërobic processes. Sand filters were operating well at rates well above 500 000 gal.; but the thing that interested me most was to see the trickling filter doing good work under most adverse conditions. These tanks are dosed by a spray from an ingenious sprinkler head designed at the station, and while more than a foot of ice had formed round the edges of the beds the area within reach of the spray was kept free and in good condition by the warmth of the sewage. (Fig. 9.)

The report which we may expect from Mr. G. A. Johnson and his associates at the station sometime next autumn will be awaited with the keenest interest. If, as seems probable, it should recommend one of the newer processes of purification, treatment on trickling beds, for example, it will mark an epoch in American practice. Its greatest significance, however, will lie in the fact that it furnishes a standard for the procedure of other communities in the design of sewage plants. While London and Birmingham and Leeds and Manchester have carried out vast experiments upon this subject, Columbus is the first American municipality to make a careful study of local conditions before the construction of a sewage disposal system. It is to be hoped that in the future this may come to be recognized as the only sensible and economical way to attack the question. There are local conditions which make the treatment of each sewage more or less a special problem. In small plants slight differences may be ignored; but no large city should install a purification system without just such an investigation as that in which Columbus has taken the lead.

Such special studies will not only throw light on purely local problems, but must add to our general knowledge of the underlying principles of sewage disposal. Each case has indeed peculiarities of its own; but certain fundamental laws may be formulated which will materially simplify the solution of

the individual problem. Thus we now know that chemical precipitation is only in exceptional cases a satisfactory process for preliminary treatment. There are numerous similar important questions still unanswered. We know that sufficient straining and settling to remove paper and garbage, gravel and silt, is always desirable. After this has been accomplished, is it generally of advantage to remove any portion of the suspended solids by fine strainers or by septic treatment, or can all the organic matter be oxidized without the production of putrescible sludge which more or less attends all anaërobic processes? When American sewage is treated in the septic tank what causes the marked variation in the results obtained? Are periods of septic action of less than twelve hours desirable? For subsequent treatment, what are the comparative merits of the contact and the trickling filter? If the trickling filter be used, what is the cheapest system for securing adequate distribution? With intermittent filters, how rapid a rate can be attained under practical conditions, and by what frequency of dosing? These are some of the general questions which press for settlement and whose solution in one set of experiments will be of value, when corrected for local differences, in every other case.

Besides the study of local conditions and the formulation of general principles of engineering practice, we need a third class of data, of a more theoretical character. The processes of sewage purification are chemical changes carried out, as we now believe, by the activity of the bacteria. Sewage treatment is undertaken in order to remove putrescible organic matter, and its efficiency must be measured by chemical tests which shall record the amount and condition of the carbonaceous and nitrogenous material. We need, therefore, more detailed studies on the methods and the interpretation of chemical analysis. As the end of the process is chemical, and its success is measured by chemical methods, so the agents which carry it out are the bacteria, and the conditions which favor or retard it must be determined by bacteriological investigations. Such researches in pure chemistry and bacteriology as are being carried out at Worcester by Prof. L. P. Kinnicutt, at Lawrence by Messrs. H.W. Clark and S. D. Gage, and at Columbus by Mr.W. R. Copeland, must furnish the data which shall lead to the practical development of the art of sewage purification in the future.

In the sewage of the South Metropolitan District of Boston there is discharged in one year 1 500 000 kg. of nitrogen in the form of free ammonia, and 500 000 kg. more as albuminoid

ammonia. To convert such vast amounts of material into an innocuous form is a problem in industrial chemistry, of no mean magnitude. It cannot be solved by rule of thumb methods. Theoretical studies, local investigations, expert construction and intelligent supervision are required satisfactorily to meet it.

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DISCUSSION.

Mr. X. H. Goodnough. — One of the most remarkable results of the investigations of Mr. Winslow is the inefficiency which these investigations have disclosed in the operation of the sewage disposal plants visited. Unpurified sewage is discharged from some of the sewage disposal works in Massachusetts, but compared with the results of Mr. Winslow's investigations the amount of sewage allowed to flow untreated into streams in Massachusetts from towns which have purification works is very small. Of the 15 sewage disposal plants of considerable size where works were originally provided for the treatment of the sewage, all of the sewage is treated at all times at 6 places, or more than one-third of those having purification works, and very little sewage is discharged untreated at 6 of the remaining places, leaving only 3 places out of the 15 at which, at the present time, any considerable quantity of sewage is allowed to escape without treatment. Of these three places the largest quantity of waste occurs at Marlboro where the flow of the sewage in the early spring is greatly increased by leakage of ground water into the sewers, and the area

available is inadequate for the purification of the sewage at such times. At Southbridge very considerable quantities of sewage are wasted at times; such waste is unnecessary, though at this place, as at Marlboro, the maximum flow of sewage is very large as compared with the average. The same is true of Natick, where much dilute sewage is allowed to escape untreated during the early spring.

The difficulty in disposing of sewage in the late winter and early spring in this climate arises from the fact that the filter beds are often covered with snow and ice for periods of many weeks in winter, when it is impracticable to remove clogging material from their surfaces, so that their capacity for passing sewage becomes reduced. At the same time, as the snow melts, the quantity of sewage discharged upon the filtration area reaches its maximum, and unless an adequate area is available to dispose of the sewage under these conditions, the discharge of a portion of the sewage without treatment must result. At those places where an adequate area of filter beds has been provided no difficulty is experienced in passing the sewage through the filters at all times, and this is the case with four-fifths of the sewage filters in Massachusetts. While, as already indicated, a greater or less quantity of sewage is discharged untreated at the majority of places in Massachusetts, the quantity so discharged is, in a large proportion of these, so small as to be of little consequence. In most such cases the discharge of untreated sewage is caused by the desire to avoid the cost of pumping at times when the flow of sewage is at its maximum and not by inadequacy of the filter beds. The temptation to discharge the excess of flow of sewage at night, at times when the sewage is very dilute, and the adjacent stream is in flood, is one which the city and town authorities in charge of sewage disposal works find it difficult to resist.

The Chairman. — One question occurred to me during Mr. Winslow's paper, — I have forgotten the name of the place where he described the filter as being made up in layers of different sized material. I would like to ask if there has been any trouble from a collection of deposits or growth at the dividing lines between the different sized materials.

Mr. Winslow. — As far as I know, there would be no way of detecting that. I know of no observation on that point. I don't think the filter had been taken to pieces.

Mr. Dwight Porter. — Mr. Chairman, I would like to

ask Mr. Goodnough if it is customary in these Massachusetts plants to deliver the sewage in winter, when it is delivered, in small doses, in short time, or whether in any case it is delivered in a steady, moderate flow.

Mr. Goodnough. — It differs at different places. At Framingham, Clinton and Brockton, for example, the sewage is all delivered in the daytime. It is collected during the night into a reservoir, and pumped usually in a period of about eight hours at the time of maximum flow. At several gravity plants the sewage is applied to the filter beds as it comes, while at other places a larger or smaller tank is used as a dosing tank to provide intermittent dosing of the beds.

Mr. Leonard Metcalf. — Mr. Chairman, like the rest of you, I have enjoyed very much the talk Mr. Winslow has given us. It seems to me he has presented the case fairly and in a well balanced way. Mr. Goodnough's words about the Massachusetts plants bring to our minds very clearly one of the essential differences in the problem in the East and in the Middle West, of which engineers sometimes lose sight. I take it that there are few who would question the fact that the slow sand filtration system is the most desirable where it is possible. Here in New England, where we have large areas of sand, which are suitable for this purpose, it is very natural that we should have developed the science along those lines, and I have no doubt that the excellence of the results which are being obtained in certain places is due very largely to the studies which have been made by the State Board of Health, and to the fact that the State Board of Health has in a way supplied that very expert supervision which has been alluded to to-night as being so necessary in order to obtain good results from sewage disposal plants. We should not lose sight of the fact that in the Middle West and certain other parts of this country the slow sand filtration system is an impossible, or at all events an impracticable one, prohibitory on account of the expense, and when an engineer is face to face with the situation of having to purify the sewage of a certain community, of course he has to bear in mind the financial question as well as the sanitary question involved. So the engineer in the Middle West and in similar regions is obliged to turn to other media than sand which he can use in order to accomplish the necessary purification.

I had an interesting problem in my own experience a short time ago in the tropics, — in Costa Rica it was, — where this point was very clearly brought out. We were short of

funds, yet it was essential to get reasonably good purification on account of the small summer flow of the stream into which the effluent was to be discharged, and coming from New England, I naturally first thought of sand filtration. Sandy areas were not to be had, however. Sand had to be brought from the sea, or from some of the rivers, at a considerable distance, with freight rates approaching a cent a pound. Sand of course was out of the question. Then I turned to cinders, or gravel or stone. Cinders were not to be had, because coal cost anywhere from $25 to $35 a ton, at times perhaps as low as $15 a ton, so that cinders were very scarce. Gravel was not to be had in suitable size in that region, which was largely a volcanic region. The next thing considered was whether bricks or similar material could be used. I investigated the brick yards to see whether there were brick-bats and accumulations of that sort, and I found that all the yards in the city did not make enough brick, let alone bats, in the course of a year to furnish material for building purposes. Then I investigated the supply of stone. Most of the material was unsuitable. I did find large bowlders along some of the streams which could be crushed or broken up by hand, and some ledges which could be utilized by carting the material for a considerable distance. Of course that made it necessary, on account of the expense of getting this material, to make use of high rates of filtration. Fortunately in that region they are not troubled with frost, so that some of the difficulties with which we meet in this latitude are not experienced there.

I cite that instance merely as showing that the problem an engineer has to face is an economic one and that he has to be governed quite as much by the financial considerations as by the sanitary considerations involved. For this reason I do not think we should condemn, broadly speaking, plants which perhaps are not operated in the winter months, without knowing about the conditions which exist in the particular towns or cities in which the plants are located. It seems to me that there are some places where it is entirely sufficient to purify the sewage during the summer months of low flow in the streams when a nuisance would be created by not doing so; whereas these same streams during the winter months would carry sufficient water to make it unnecessary to adopt any method of disposal other than dilution.

That suggests to me reference to one remark which Mr. Winslow made about the septic tanks, — I take it he would

not condemn septic tanks for all localities. It occurs to me, that there are locations along the seashore, for instance, where all that is necessary is to remove the greater part of the floating matter, the paper, etc. If it is only paper that is to be removed, that can be done by screening racks; but if we go beyond that, the septic tank is perhaps the cheapest thing to use to accomplish the ends desired. In the same way, in certain rivers, where there is necessary water to give sufficient dilution, all that is necessary may be to take the coarser matter out of the sewage.

I confess that I have come to feel, from my present knowledge of the subject in these other districts to which I have alluded, that the most hopeful line of investigation now is towards the trickling filter, or something akin to that, rather than the use of the septic tank and contact beds. I think considerable work is yet to be done, but we must all welcome the work being done in Columbus, and hope that it will be the beginning of similar investigations.

Mr. Coffin. — Mr. Chairman, I have been much interested in the papers to-night. The comparison of the Massachusetts system of sand filtration with these other systems brought to my mind an incident which, in a way, was rather amusing, and which showed that while in sewage matters the critic may not be obliged to know very much about his subject, yet it is desirable in a way to know something about it. Several years ago I was called upon to design a system of purification for the Pictou County Insane Asylum in Pictou, Nova Scotia, a small plant, where the conditions were very difficult. The effluent must necessarily go into the river, which not very far below was being used as a source of water supply for another town. The asylum was situated in a valley of this river, and it was impracticable to pump it over the divide. My only consolation was, that the sewage was already going into the river, and if I were fairly careful I could not make matters very much worse. I studied the matter carefully and finally fell back on the good old Massachusetts way and hauled sand eight miles to build an intermittent sand filter. I advised the authorities of the asylum that if they ran the filter carefully it might purify the sewage sufficiently, but it might be necessary to put in a second sand filter to filter the effluent before it was turned into the river.

We put the filter in, built it in the ordinary manner, with underdrains and 5 ft. in depth of sand, put in a dosing tank, and

set it at work; it was hardly running before the people of New Glasgow, the town below, got nervous about drinking the sewage. It hadn't troubled them much before when they were taking it straight, but they did not like the idea of its going through a filter. So they employed an engineer to investigate it and he made a report. The first few pages were devoted to the theory of sewage purification, and treated of bacteriology and chemistry and other things; finally he came to the subject in hand and said that this plant was evidently intended for a bacteriological plant or septic system, but the designers had in some way been misled and it was not built in accordance with the correct theory of a bacteriological disposal plant. He said, in substance, that in the first place the septic tank was not properly designed, that instead of sewage passing slowly through the tank, it was discharged suddenly and periodically on to the beds, which prevented any proper septic action. In the next place, the beds were not properly contact beds. The sewage could not be controlled, there was no means of retaining it on the beds or of drawing it off; it apparently could only soak away in the sand; and in fact the whole thing was not designed in a proper manner. He said he had made no tests of the effluent, but he had examined it, and it was clear and colorless, but this was not conclusive of its purification (laughter) and the whole thing must be condemned. He advised that it be abandoned as it was not safe, and by inference that the asylum should go back to the old system of discharging the sewage into the river in a crude state. The thing was referred to the Health authorities there, and, finally, after a great deal of discussion and explanation, the operation of the filter was allowed to go on, and, so far as I know, it is going on to-day. (Laughter and applause.)

The Chairman. — It has been suggested that I ask Mr. Winslow regarding the odor from the Allis-Chalmers Company. I think it would be interesting to know if Mr. Winslow took along his olfactory organs as well as his organs of sight.

Mr. Winslow. — Mr. President, there is no odor whatever at Allis even from the trickling filters, except the odor of hot steam. Very few of the plants were obnoxious. Of course, they would be better at this season of the year than at other times. I remember at East Cleveland that there was considerable odor, and at Westerville there was a noticeable odor of sewage from the imperfectly dosed beds. Those are the only two plants at which there was any odor.

Mr. R. S. Weston. — May I ask Mr. Winslow what he means by odor; whether it is what an expert would call odor or what a citizen of the town calls odor?

Mr. Winslow. — I have been a plumbing inspector, and I think I am pretty well trained in the sense of smell, and really I don't think the odor was noticeable in the other plants. There was odor in the septic tanks, but walking or driving by I don't think there was any odor which would be noticeable.

Mr. G. A. Carpenter. — I feel like adding my word of commendation of the paper read by Mr. Winslow, knowing that we have in this paper the evidence of an impartial witness, taken at those plants when they were acting under extremely difficult conditions, which is something we seldom get when we receive the reports of plants first installed. I remember, and I think most of us recall, in almost all the plants shown, that at the first installation data were published regarding the details of the plants, and it was assumed that they were going to get a perfectly pure and satisfactory effluent without any further attention. I think in one particular instance — I am almost sure it is one of the plants spoken about — that I remember that after the plant was installed it was to be practically locked up and it would act continuously without giving any further trouble. I think most of us who have had any practical experience at all in the operation of sewage disposal plants have encountered a different condition of affairs entirely, and I feel that reports of this kind by impartial witnesses, going into detail as Mr. Winslow has done, are extremely valuable,.

Mr. Porter. — Mr. President, it seemed to me, in casually looking over recent annual reports of the State Board of Health, that in advice to towns in regard to the disposal of sewage there seemed to be a little tendency to discourage the use of the septic tank. Perhaps I didn't get the right impression. If I did, was it due to the conviction that they ought to be discouraged, or simply because of special circumstances in these cases? Perhaps Mr. Goodnough can explain it.

Mr. Goodnough. — Possibly such inference may have been drawn from some replies to the Board relative to certain sewage disposal cases. Each case is, however, considered on its merits, and I do not think there has been any expression of disapproval of the septic tank, because it was a septic tank, but because the plan was not adapted to the locality in question.

I think Mr. Metcalf has called attention very clearly to the difference in the problems in the different parts of this country. There is a difference and a very distinct difference. I have seen no cases in Massachusetts as yet where it was very difficult to convey the sewage to some area of land suitable for the purification of sewage, and we know, from our experiments at Lawrence and the experience from the plants now in operation, that by that method better results can probably be secured than in any other way, and probably at less expense, but there may be cases arising here, as in other states, in which there is no area readily available adapted to the purification of sewage or intermittent filtration. In such cases I think the Board would approve any system that would do the work and do it satisfactorily for the place in question.

Data appended by Mr. Winslow copied from reports by Mr. Shields and Mr. Pratt.

ANALYSES OF SEWAGE AND EFFLUENTS.

(SHIELDS, 1904.)

Data in parts per 1 000 000.

LOCALITY.	Total Residue.	Fixed Residue.	Volatile Matter.	Oxygen Consumed.	Nitrogen as	
					Free Amm.	Alb. Amm.
Lake Forest, Ill.						
Raw Sewage	725.6	526.0	199.6	57 5	11.2	5.3
Tank Effluent	1387.2	1012.0	375.2	375.0	20.0	9.4
Filter Effluent	667.2	556.0	111.2	7.9	.48	0.3
Allis-Chalmers Co.						
Raw Sewage*						
Tank Effluent	541.	390.	151.	1.5	Trace	.16
Filter Effluent	542.	380.	162.	2.8	.03	.16

LOCALITY.	Nitrogen as		Bacteria.	Per Cent. Purification.	
	Nitrites.	Nitrates.		Alb. Amm.	Bacteria.
Lake Forest, Ill.					
Raw Sewage	.000	0.16			
Tank Effluent	.002	0.84		19.60	
Filter Effluent	.080	8.00		9.70	
Allis-Chalmers Co.					
Raw Sewage*			700 000		
Tank Effluent	.11	1.80	15 000		98.
Filter Effluent	.14	1.25	14 000	.00	98.1

*No chemical analysis.

Analyses of Sewage and Effluent from Ohio Plants

(Pratt, 1905.) — Parts per 1 000 000

L. S. & M. S. R.R. SHOPS, COLLINWOOD

Description of Sample.	Date and Hour of Collection.	Color.	Turbidity.	Sediment.	Odor.	Oxygen Required.	Nitrogen as Albuminoid Ammonia.	Nitrogen as Free Ammonia.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Alkalinity.	Incrusting constituents.	Solids. Total.	Solids. Suspended.	Loss on Ignition Total.	Loss on Ignition Suspended.	Bacteria per cc.
Effluent	Nov., 1903, 9 A.M. . .	40	v. s.	s.	5 musty	7.16	.520	3.900	.140	.8	19.4	158	74	358	28	66	9	
Effluent	Nov., 1903, 9 A.M. . .	40	v. s.	s.	5 musty	11.94	.820	6.020	.170	.4	18.9	131	67	350	15	59		
EAST CLEVELAND.																		
Effluent from works . .	April 19, 1903 . . .	20	tr.			8.92	1.660	4.000	.080	6.00	33.6							8,200
Effluent from works . .	Nov. 10, 1903 . . .	40	tr.	tr.	1 musty	7.16	0.470	2.550	.140	22.0	44.6	94	70	449	30	142	129	
MANSFIELD.																		
Sewage—main sewer .	Sept. 8, 1902, 7 A.M.–6 P.M. .	30 dk.		s.	5 oily	55.99	3.710	6.450	none	tr.	49.7	313	37	663		218		
Sewage—main sewer .	Sept. 8–9, 1902, 7 P.M.–6 A.M.	23		s.	5 oily	48.45	3.520	3.920	tr.	none	31.7	303	25	1,029		215		
Sewage—main sewer .	Jan. 27, 1904, 8 A.M.–8 P.M. .	40		cons.	3 sew.	13.80	2.090	6.430	tr.	tr.	41.3	346		613	143	142	85	
Sewage—main sewer .	Jan. 27–28, 1904, 9 P.M.–8 A.M.	30		distinct	2 sew.	6.20	.520	1.660	.140	2.0	28.8	306		542	49	112	14	
	Average	31				32.11	2.460	4.615	.035	0.5	37.9	317		712		172		
Sewage—exit septic tank .	Sept. 8, 1902, 7 A.M.–6 P.M. .	35 dk.		s.	5 oily	19.89	1.600	6.080	tr.	none	44.7	299	41	522		141		
Sewage—exit septic tank .	Sept. 8–9, 1902, 7 P.M.–6 A.M.	35 dk.		s.	5 oily	16.90	1.430	6.400	none	none	43.1	298	47	522		133		
Sewage—exit septic tank .	Jan. 27, 1904, 8 A.M.–8 P.M. .	40		cons.	3 sew.	11.52	1.580	4.980	.160	none	31.9	285		526	62	91	6	

Sewage—exit septic tank .	Jan. 27–28, 1904, 9 P.M.–9 A.M.	30 off		distinct	4 sew.	10.92	1.800	4.940	.160	none	33.6	309		532	49	110	35
	Average	35				14.81	1.600	5.600	.080	none	38.4	298		526		119	
Effluent from works . .	Sept. 8, 1902, 6 P.M. . .					2.47	.470	1.570	.125	2.0	36.0						
Effluent from works . .	Sept. 8–9, 1902, 6 A.M. . .					4.00	.475	1.920	.170	1.5	38.4						
Effluent from works . .	Jan. 27, 1904, 8 A.M.–8 P.M. .	20	8	v. s.	2 oily sew.	3 80	.500	2.130	.070	7.0	28.8	219		514	27	95	12
Effluent from works . .	Jan. 27–28, 1904, 9 P.M.–8 A.M.	10	tr.	v. s.	2 oily sew.	3.28	.570	1.960	.120	7.0	31.4	227		530	11	88	6
	Average					3.39	.503	1.895	.121	4.4	33.6						

OHIO STATE REFORMATORY.

Effluent	Ind. May 4, 1899, 9.20 . . .	35	v. s.	s.	moldy	8.54	.561	4.750	.112	11.14	82.0	79	68	513		176	
Effluent	Ind. May 29, 1899, 6.05 P.M.	50	v. s.	s.	strong musty	5.87	.280	1 760	.190	22.98	66.4	71	30	567		269	
Effluent, day . . .	Comp. May 27, 1902, 7 A.M.–6.15 P.M.	42	.16	s.	2 musty	7.44	.630	3.350	.100	9.60	43.8	78		350		84	
Effluent, night . . .	Comp. May 27–28, 1902, 7 P.M.–6 A.M.	41	.16	v. s.	faint musty	7.12	.770	4.065	.160	10.00	40.8	78		403		156	
Effluent	Comp. May 27, 1902, 6 A.M. . .									9.00	45.8						
Effluent	Ind. May 27, 1902, 12 A.M. . .									8.80	45.8						
Effluent	Ind. May 27, 1902, 6.15 P.M. .									10.00	40.6						
Effluent	May 27, 1902, 12 P.M. . .									11.20	39.6						

WESTERVILLE.

Sewage—main sewer .	Comp. Feb. 10, 1904, 1–5 P.M. . .	30 off	308	con.	3 sew.	167.88	9.605	5.750	.016	none	79.2	501	198	1 588	116	652	106
Sewage—exit septic tank .	Feb. 10, 1904, 1–5 P.M. . .	30 off	60	con.	sew.	42.82	2.110	4.250	.046	none	42.4	475	212	1 158	12	342	36
Effluent	Feb. 10, 1904, 1–5 P.M. . .	tr.	tr.	v. s.	none	2.20	.240	.636	.026	4.0	39 4	388	214	1 100		292	

Association of Engineering Societies.

Vol. XXXIV. JANUARY, 1905. No. 1.

PROCEEDINGS.

Engineers' Club of St. Louis.

588th Meeting, St. Louis, December 7, 1904.—Held at the Club rooms, 709 Pine Street, Wednesday evening, December 7, 1904. President Ockerson presided. Twenty-four members of the Club were present.

The minutes of the 587th meeting were read and approved, and the minutes of the 378th meeting of the Executive Committee were read.

Mr. W. H. Bryan, on behalf of the World's Fair Committee, stated that arrangements were now under way for the annual dinner, which would probably be held on the regular evening, Wednesday, December 21st.

Professor Van Ornum presented a motion to the effect "that the President appoint three members to represent the Club in a movement now on foot for a revision of the building laws of the city." After some discussion the motion was lost by a vote of nine to seven.

Mr. W. H. Bryan read a telegram from Col. E. D. Meyer, stating that a resolution favoring the continuation of the work of the United States Geological Survey Coal-Testing Plant had been adopted by the American Society of Mechanical Engineers in session at this time in New York City.

The Executive Committee was instructed to formulate the proper letter to the Western Society of Engineers of Chicago, expressing the appreciation of the Club for the many courtesies extended during the recent trip to Thebes, Ill. The matter was referred to the Secretary for action.

Mr. A. P. Greensfelder moved "that the Entertainment Committee of the Club to be appointed for the year 1905 be increased from three to five members, and that such committee be instructed by the Club to arrange excursions for the Club to various places of interest at least once every two months." Professor Langsdorf suggested that the motion be amended by inserting in place of the words "once every two months," "at discretion of committee." Mr. Brenneke suggested that it be amended to read "about six excursions during the year." This amendment was accepted by Mr. Greensfelder, and the motion, as amended, was carried. The motion as amended reads: "That the Entertainment Committee of the Club, to be appointed for the year 1905, be increased from three to five members, and that such committee be instructed by the Club to arrange for the Club to make about six excursions during the year to various places of interest."

Mr. C. D. Purdon suggested that some arrangement be made to have the discussions of the papers presented at the various meetings preserved and published.

Mr. Seth D. Merton was elected to membership in the Club.

Mr. Wm. T. Simpson, Jr., was proposed for membership, and his application was referred to the Executive Committee for approval.

Mr. Brenneke, chairman of the Nominating Committee, presented a letter from Mr. Robert Moore, stating that it would be impossible for him to accept the Presidency of the Club for the ensuing year on account of other engagements, and requesting that his name be removed from the list presented by the Nominating Committee. The Nominating Committee requested the privilege of withdrawing their report made at the last meeting, and substituting another name in place of Mr. Moore's. The privilege was granted by the Club, as requested, and the committee substituted the name of Mr. Edward Flad. Other nominations were called for, and the name of Mr. H. H. Humphrey as a candidate for the Presidency was presented in due form, as required by the by-laws. There were no further nominations for the other offices, and upon motion of Mr. Colby the nominations were closed.

The reports of the officers and committees were then received. Mr. Ockerson, the President of the Club, stated that the report of the Executive Committee would be deferred to a later date.

The report of the Secretary was then presented, and was formally received and ordered filed.

The report of the Treasurer was presented, and upon motion of Mr. Zeller, was referred to the Executive Committee to be audited.

The report of the Librarian and that of the Board of Managers were both received and ordered filed.

The report of the Governing Board of the Associated Technical Clubs, which was next presented, contained the following recommendation: "That when the business of the Governing Board has been finally settled between the various technical clubs, the Governing Board be abolished, and that the Librarian be made custodian of the new quarters." Professor Van Ornum moved that the report be received and filed, and that the request be adopted when the duties of the present Board shall have ceased. The motion was carried.

Reports of the Entertainment Committee and the World's Fair Committee were both received and ordered filed.

No report was presented by the Committee on Smoke Prevention.

The President called attention to the fact that this was the last meeting of the Club at the present quarters. The next meeting of the Club, being the annual dinner, would naturally be held elsewhere, and the first meeting in January would be held at the new quarters of the Club in the Academy of Science Building.

Adjourned. R. H. Fernald, *Secretary.*

589th Meeting, St. Louis, December 21, 1904.—The annual dinner of the Engineers' Club of St. Louis was held at the Hamilton Hotel, Hamilton and Maple Avenues, Wednesday evening, December 21st, President Ockerson presiding.

There were thirty-one members and fourteen guests present. Of the latter the following were guests of the Club: Dr. J. A. Holmes, Chief of the Department of Mines and Metallurgy, World's Fair; Professor A. O. Lovejoy, Washington University; Dr. Theodor Lewald, Commissioner General

for Germany to the Exposition; Dr. W. J. McGee, Chief of the Department of Anthropology, World's Fair; Mr. E. W. Parker, of the U. S. Geological Survey Fuel Testing Plant; Mr. W. B. Stevens, Secretary of the Exposition Co.; Capt. C. H. Smith, of the Westinghouse Co.; Professor C. M. Woodward, of Washington University; Colonel C. M. Watson, Commissioner General for Great Britain to the Exposition.

After the dinner, President Ockerson presented a brief address and introduced the following gentlemen, who addressed the Club on the subjects indicated: Dr. Theodor Lewald, "The Engineering Exhibits of Germany"; Dr. J. A. Holmes, "Tests of Fuel and Structural Material"; Mr. Richard McCulloch, "Things Across the Water"; Col. C. M. Watson, "Relations of American and British Engineers"; Mr. E. W. Parker, "The Fuel Problem;" Dr. W. J. McGee, "The Aims of Anthropology."

At the conclusion of these remarks the President announced that the result of the election of officers for the year 1905 was as follows:

Total number of votes cast, 131.

For President (one to be elected) (Irregular, 10)—Edward Flad, 84; H. H. Humphrey, 37.

For Vice-President—W. A. Layman, 129.

For Secretary—R. H. Fernald, 129.

For Treasurer—E. E. Wall, 130.

For Librarian—E. B. Fay, 130.

For Directors (two to be elected)—A. P. Greensfelder, 126; H. H. Humphrey, 122; Edw. Flad, 2; A. S. Langsdorf, 1.

For Members of the Board of Managers of the Association of Engineering Societies (two to be elected)—H. C. Toensfeldt, 131; C. A. Moreno, 130.

Adjourned. R. H. Fernald, *Secretary.*

590th Meeting, St. Louis, January 4, 1905.—The meeting was held at the new Club rooms, 3817 Olive Street, Wednesday evening, January 4, 1905. President Flad presided. Forty-five members and four guests were present.

The minutes of the 588th and 589th meetings were read and approved, and the minutes of the 380th and 381st meetings of the Executive Committee were read.

Mr. Wm. T. Simpson, Jr., was elected to membership in the Club.

The following applications for membership were presented and referred to the Executive Committee:

James Adkins, Jr., Archibald L. Anderson, Gurdon Gilmore Black, James T. Dodds, Wm. August Hoffman, Arthur I. Jacobs, Cloyd Marshall, Wilfred Van Ness Powelson, Charles Winfield Trowbridge.

The Secretary was instructed to send a vote of thanks of the Club to the Committee on New Quarters for the splendid work which they had accomplished in getting the quarters ready for the first meeting in January, and for the very attractive appearance which the rooms present.

A vote of thanks was extended to the United Railway Company, through Mr. Richard McCulloch, for its kindness in furnishing cars during the visit of the Western Society of Engineers of Chicago.

The Secretary was instructed to express the thanks of the Club to the

American Society of Civil Engineers for the maps and charts presented to the Engineers' Club of St. Louis.

Following the business of the evening the Club indulged in an informal smoker with frequent outbursts of good speeches and stories, not the least of which was the brief address of the new President, Mr. Edward Flad, which, owing to his absence on the night of the annual dinner, was missed at that time.

After a very enjoyable evening in the new quarters, the Club adjourned.

R. H. FERNALD, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, DECEMBER 21, 1904.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., President Frederick Brooks in the chair; fifty-two members and visitors present.

The record of the last meeting was read and approved.

William L. Butcher and John Cunliffe, Jr., were elected members of the Society.

The President announced the death of Macy S. Pope, a member of the Society, which occurred December 10, 1904, and by vote of the Society the President was requested to appoint a committee to prepare a memoir. The following committee has been appointed—Messrs. Leonard Metcalf, A. E. Burton and L. F. Baldwin.

On motion of Mr. Adams, of the Excursion Committee, the thanks of the Society were voted to Messrs. Nawn & Brock for courtesies extended to its members on the occasion of the visit to the work now in progress for the abolition of grade crossings in East Boston.

The first paper of the evening, entitled "Massachusetts Northern Boundary," by Nelson Spofford, was read by his son. The compass used by Richard Hazen in running the boundary line in 1741 was exhibited and also a number of maps showing the various lines which have been run.

Mr. F. W. Hodgdon had thrown on the screen a number of photographs of the boundary stones which have been set on the line.

Prof. L. J. Johnson read the second paper, entitled "Some New Data on the Weight of a Crowd of People," which was illustrated by lantern slides.

Prof. C. M. Spofford gave the results of some experiments he had made to ascertain the weight of a crowd of people.

A memoir of Kilburn S. Sweet, prepared by a committee of the Society, consisting of Profs. Dwight Porter and C. M. Spofford, was read by Professor Spofford.

Adjourned. S. E. TINKHAM, *Secretary.*

Civil Engineers' Club of Cleveland.

CLEVELAND, JANUARY 10, 1905.—The regular January meeting of the Club was called to order at 8.30 P.M. by Dr. D. C. Miller, Vice-President, with fifty-three members and visitors present.

Messrs. Colegrove and Dutton, tellers, reported the election to active

membership of Herman Smith Johannsen, Joseph Ralph Poe, B.S. and Arthur Elisha Spooner, C.E.

The following applications for active membership, approved by the Executive Board, were read by the Secretary: L. O. R. Clark, H. J. Desson, Wm. L. Ely, H. C. Gammeter, A. E. Johnson and Morris S. Towson.

Balloting for a Nominating Committee, for officers for the ensuing year, resulted in the selection of the following: F. C. Osborn, Harry Fuller, F. E. Bissell, Dr. C. S. Howe, H. M. Lucas, Prof. F. H. Neff and W. A. Stinchcomb.

The paper of the evening, "Foundation Soils of Cleveland," was read by Mr. W. J. Carter, C.E., City Engineer, and was discussed at length by Mr. H. M. Lane, M.E., Prof. Dutton, Mr. Augustus Mordecai, C.E., and others.

Adjourned.

JOE. C. BEARDSLEY, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., JANUARY 9, 1905.—The twenty-second annual meeting of the Civil Engineers' Society of St. Paul was held at the Merchants Hotel at 6.30 P.M.

Present, 23 members and 5 visitors; President Starkey in the chair.

Minutes of the previous meeting were read and approved.

The reports of the President, Secretary, Treasurer and Librarian were read and accepted.

The government of the Society was authorized to provide additional shelving for the library and expend $50.00 for books.

President Starkey was re-elected on the first ballot, and the Secretary was instructed to cast a ballot for the re-election of all the other officers.

Prof. Weitbrecht presided at the banquet following the meeting, and directed the entertainment most happily until nearly midnight.

Responses to his call were as follows: L. W. Rundlett—"Concrete-steel Construction." H. B. Avery—"The Minneapolis Engineers' Club." A. R. Starkey—"A Short Look Ahead." E. E. Woodman—"The Engineer as a Social Factor." H. H. Harrison—"A Broken Flywheel." Wm. Danforth—"The County Surveyor." Oscar Claussen—"The Engineer as a Sportsman." Geo. L. Wilson—"Electric Railway Advances." C. A. Forbes—"Le Vieux Temps." H. J. Bernier—"Aggression." K. W. Tanner—"Tenacity." J. Henry Fitz—"Mining Mysteries." Geo. Z. Heuston—"Outlook from a Sidetrack." H. E. Stevens—"The Panama Canal." A. H. Wheeler—"Getting a Foothold." W. A. Somers—"Assessing by Guess and by Rule." W. R. Hoag—"Civic Responsibility."

C. L. ANNAN, *Secretary.*

Montana Society of Engineers.

THE regular monthly meeting of the Society was held at the Society headquarters, room 16, Leyson Block, on Saturday evening, December 10, 1904, with President Moulthrop in the chair and a goodly number of the members present.

The minutes of the previous meeting were read and approved.

Messrs. Peter Kendrick, of Walkerville, and Henry Ward Rowley, of

Billings, were elected to membership in the Society by a unanimous vote. Under suspension of the rules, the application of George Brown Couper, of Bozeman, was read, approved and the Secretary was instructed to send out the ballot and invite Mr. Couper to attend the annual meeting. The Secretary reported the death of William Monroe, a member of the Society, and Messrs. Carroll and Dunshee were appointed by the Chair to draft proper resolutions to be presented at the next meeting.

It was decided that the Eighteenth Annual Meeting of the Society shall be held Friday and Saturday, January 13 and 14, 1905, at Butte, Mont.

The Secretary read a communication from Mr. Arthur H. Wethey relating to the mining laws of Montana, and the Chair appointed Messrs. H. V. Winchell, Gillie and Wethey to present a report on same at annual meeting.

Prof. Bowman consented to present a paper at the annual meeting on "Stresses in a Gallows Frame," and Messrs. Carroll and Starz one on sulphate of copper as a means of water purification. Mr. E. J. Strasburger of Cerre de Pasco, Peru, will also have a thesis on "Railways of Peru." A discussion of the United States mining laws will also be a part of the program at the annual meeting. The committees on transportation reported the usual railroad rates of one and one-third fare for the round trip.

The headquarters of the Society during the annual meeting will be in rooms 25 and 26, Lewisohn building, West Granite Street.

The Society then adjourned.

Clinton H. Moore, *Secretary.*

Engineers' Society of Western New York.

Annual Meeting, Buffalo, N. Y., December, 1904.—The meeting was held in the rooms of the Society, 533 Ellicott Square, at 4 p.m., and at the Teck Café in the evening of December 6, 1904.

There were present Messrs. Babcock, Norton, Knapp, Speyer, Kielland, Dark, Haven, Thorn, Bapst, Wilson, Fell, Lyon, Eighmy, Fairchild, Ricker, Meyer, Elias, Bardol and Alverson.

The minutes of the last meeting were read and approved. Mr. Haven, the member for the Society, of the Board of Managers of the Associated Societies, read some correspondence with the Chairman and Secretary of that Association relative to some changes in the rules.

Messrs. Knapp and Kielland were appointed tellers to count the ballots for officers of the Society. The President announced the following-named persons as having been duly elected:

President—George H. Norton.

Vice-President—Horace P. Chamberlain.

Director—Alfred T. Thorn.

Secretary—Harry B. Alverson.

Treasurer—Frank N. Speyer.

Librarian—William A. Haven.

The annual reports of the Secretary and the Treasurer were read and referred to the Auditing Committee to be appointed by the President; they were ordered to be printed and sent to the members.

The Librarian said that owing to his absence from the city this fall, he had not prepared any report, but would do so soon.

On motion of Mr. Knapp, duly seconded, the following addition to the by-laws was read and adopted by the Society.

Addition to Article III, Section 2.

"Applications of persons not resident of North America, and who may be so situated as not to be personally known to three (3) members, may be recommended for ballot by the Executive Board, after having secured evidence sufficient, in their opinion, to show that the applicant is worthy of admission."

The amendments to the constitution and by-laws that were read and approved at the meeting of the Society, November 1st, were again read, approved and ordered to be printed and submitted to letter ballot, to be counted at the regular meeting, January 3, 1905.

Amendment to Article IV of the By-Laws.

addition to sec. 12.

"The payment at one time of seventy-five ($75.00) dollars by any member not indebted to the Society, shall constitute him a life member, and he shall be exempt from all future annual dues.

"Any person who has been a member of the Society for twenty (20) years shall be exempt from all future dues or assessments of any kind."

Note.—This amendment was unanimously adopted by ballot.

President Babcock made a short address on the state of the Society, and took occasion to thank the members of the Executive Board for their interest in the affairs of the Society and their punctual attendance at the meetings and for their assistance to him during the past year.

Votes of thanks to the retiring officers were unanimously adopted.

During the evening session informal remarks on the affairs of the Society and engineering matters in general were made by Messrs. Norton, Lyon, Kielland, Ricker, Bapst, Wilson, Meyer, Babcock, Haven, Elias, Dark and others, and, after a social evening, the meeting adjourned about midnight.

H. B. Alverson, *Secretary.*

Annual Report of Treasurer.

Buffalo, N. Y., December 5, 1904.

Engineers' Society of Western New York:

Gentlemen,—As your Treasurer, it is my pleasure to submit the following report:

receipts.

Balance in Treasury, December 1, 1903	$318.34
From Secretary and others	593.50
From banks, Interest	12.14
Total	$923.98

disbursements.

Rent, October, 1903, to September, 1904, inclusive	$276.00	
Five quarterly assessments, A. E. S.	169.50	
Postage, printing and stationery	52.55	
Binding magazines, etc.	19.25	
Subscriptions for magazines, etc.	20.70	
Stenographer and typewriting	13.55	
Annual dinner	33.10	
Advertisements	19.60	
R. G. Dunn & Co.	5.50	
Erie County Bank	312.82	
Fidelity Bank	1.41	
		$923.98

BALANCE ON HAND.

General Fund	$0.31	
Library Fund	60.61	
Permanent Fund	253.31	
		$314.23

With a balance of thirty-one cents in the treasury of the General Fund, I have in my possession bills due and requiring payment as follows, viz:

Three months' rent	$69.00	
Printing and postage	10.40	
Association E. S. printing	6.50	
Typewriting	2.92	
Borrowed to pay 3d quarterly assessment	2.00	
Postage and general expenses	12.42	
		$103.24

Respectfully,

F. N. SPEYER, *Treasurer.*

ANNUAL REPORT OF THE SECRETARY FOR THE YEAR DECEMBER 1, 1903, TO DECEMBER 1, 1904.

BUFFALO, N. Y., December 6, 1904.

TO THE PRESIDENT AND MEMBERS OF THE ENGINEERS' SOCIETY OF WESTERN NEW YORK:

Gentlemen,—I beg to submit the following annual report for the year ending December 1, 1904:

MEMBERSHIP.

Total membership December 1, 1903	83
Total membership December 1, 1904	85
Consisting of—	
Honorary member	1
Members	66
Associates	13
Juniors	4
Temporary member	1
	85

There are three of the above members who have resigned, to take effect January 1, 1905.

RECEIPTS AND DISBURSEMENTS.

Entrance fees, 2	$10.00	
Annual dues	401.25	
Journal advertisements	140.00	
Key deposit	.25	
Annual banquet	12.00	
From former Secretary	28.00	
		$591.50
Deposited with the Treasurer		$591.50

MEETINGS.

The Society has held seven meetings, with an average attendance of nine members, as against eight meetings, with an attendance average of twelve in the previous year. Owing to a lack of quorum three meetings were not held. One inspection trip to the plant of the Lackawanna Steel Co., with an attendance of twenty-seven, was made.

Papers were given at the meetings as follows:

March 1st—"A Broad Plan for the Improvement of the Niagara Frontier between Buffalo and the Falls, Including the Development of the Niagara River," by Mr. O. S. Garrettson.

April 5th—"The Utilization of Niagara Falls Power," by Mr. H. W. Buck.

May 5th—"The Silicate of Lime Stone Process," by Mr. Adsit, and "The Cornell Steel Lath," by Mr. Harrower.

Twelve meetings of the Executive Committee were held, with an average attendance of five. In this connection it may be noted that the Executive Committee formed 60 per cent. of the average attendance at the regular meetings.

Very respectfully,

H. B. ALVERSON, *Secretary.*

MAP

Showing the locations of the Societies forming

THE ASSOCIATION OF ENGINEERING SOCIETIES.

(Each dot represents a membership of one hundred, or fraction thereof over fifty.)

Association of Engineering Societies.

Vol. XXXIV. February, 1905. No. 2.

PROCEEDINGS.

Civil Engineers' Club of Cleveland.

Cleveland, February 14, 1905.—The regular meeting of the Club was held in Electricity Building, Case School of Applied Science, in the large auditorium, and was called to order by Dr. D. C. Miller, Vice-President.

The Club had as its guests the Cleveland Foundry Foremen's Association, the subject of the paper for the evening being of especial interest to them. There were present about 300 members and guests.

The Nominating Committee, through its Chairman, Mr. F. C. Osborn, presented the following nominations for officers of the Club for the ensuing year: For President, Bernard L. Green, C.E.; for Vice-President, Dr. Dayton C. Miller; for Secretary, Joseph C. Beardsley; for Treasurer, Arthur G. McKee, M.E.; for Librarian, Elmer B. Wight; and for Directors, Col. Dan C. Kingman, U.S.A., and Charles H. Wright, C.E.

The tellers reported the election to active membership of Messrs. L. O. R. Clark, M.E., H. J. Desson, Wm. L. Ely, H. C. Gammeter, Allen E. Johnson and Morris S. Towson, C.E.; and the Secretary read the following applications: Messrs. H. J. C. Freyn, M.E.; H. A. Gilbert, Ph.B.; F. E. Hulett, M.E.; F. J. Littell, M. E.; Chas. H. Little, Franklin Moeller, M.E.; H. E. Scott, C.E.; W. H. Thompson, M.E., for active membership; Mr. Geo. N. Pifer, for associate membership; and Mr. R. S. Moore, M.E., Portsmouth, Ohio, for corresponding membership.

Tellers also reported that fifty-three ballots were cast for and one against the proposition to transfer $700 from the Permanent to the General Fund. The Chairman therefore declared that the proposition had carried.

The paper of the evening, "Thermit," was read by Dr. Stutz, Vice-President of the Goldschmidt Thermit Company, and was accompanied by many demonstrations of the uses to which this new process has been put, such as the welding of street railway rails, wrought-iron pipe, etc.; the boring of a hole in a ¾-inch iron plate, which was afterward filled up again by a similar process, etc.

Joe C. Beardsley, *Secretary.*

Boston Society of Civil Engineers.

Boston, January 25, 1905.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 o'clock P.M., President Frederick Brooks in the chair; nineteen members and visitors present.

The record of the last meeting was read and approved.

Messrs. Herbert W. Olmsted and Frank L. Toof were elected members of the Society.

The President stated that under the By-laws it was necessary at this meeting to choose a committee to nominate officers, and, on motion, it was voted that members of the committee be nominated from the floor. As the result of such nominations the following committee was chosen to nominate officers for the ensuing year: Messrs. Robert S. Weston, Wm. S. Johnson, F. W. Hodgdon, G. A. Kimball and I. E. Moultrop.

Mr. Henry Manley was appointed a committee to make the necessary arrangements for the annual dinner of the Society.

The President announced the death of Charles M. Wilkes, a member of the Society, which occurred on January 7, 1905, and, in accordance with the usual practice, that a committee would be appointed to prepare a memoir. The following have been selected as members of that committee: Messrs. Howard A. Carson and Gaetano Lanza.

On motion of Mr. Adams, of the Excursion Committee, the thanks of the Society were voted to Mr. George Phillips, Deputy Superintendent of the Sewer Division of Boston, for courtesies extended to members of the Society on the occasion of the visit to the works of the sewer department under construction at the Back Bay Fens on Thursday, January 12, 1905.

Mr. Irving E. Moultrop read the paper of the evening, entitled "The Steam-turbo Generator Station of the Edison Electric Illuminating Company of Boston." The paper was very fully illustrated by lantern slides. The paper was briefly discussed by Mr. Leonard Metcalf and others.

Memoirs of the following members, which had been prepared by committees of the Society, were read: James T. Boyd, Reuben Shirreffs and Macy S. Pope.

Adjourned. S. E. Tinkham, *Secretary.*

Boston, Mass., February 15, 1905.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 o'clock P. M., President Frederick Brooks in the chair. Sixty-three members and visitors present.

The record of the last meeting was read and approved.

Messrs. Henry E. Cowan, Charles S. Shaughnessy, George P. Shute and Theodore W. Souther were elected members of the Society.

A communication was read from the Executive Committee representing a joint committee appointed by the Twentieth Century Club, the Boston Society of Architects, the Municipal Improvement League and the Massachusetts Civic League for the purpose of gathering information and material bearing upon municipal improvement, asking this Society to join in the undertaking by the appointment of a committee to represent it. On motion it was voted to refer the matter to the Board of Government for investiga-

tion. Later in the meeting Mr. Ralph Adams Cram, of the Executive Committee, explained briefly the object desired to be gained by the collection of the information on municipal improvement.

The thanks of the Society were voted to Mr. W. C. Fish, Manager of the Lynn works of the General Electric Co., and to Mr. G. H. Stickney, its engineer, for courtesies extended to members of the Society on the occasion of the visit to the Lynn works this afternoon.

The thanks of the Society were also voted to the Edison Electric Illuminating Co. for their kindness in arranging for the inspection of their plant at South Boston, on January 25th.

Mr. David A. Harrington read the paper of the evening, entitled "Underground and Submarine Conduits for Electric Wires." The paper was very fully illustrated with lantern slides. A general discussion followed the reading of the paper.

Adjourned. S. E. TINKHAM, *Secretary.*

Engineers' Club of St. Louis.

591ST MEETING, ST. LOUIS, JANUARY 18, 1905.—Held at the Club rooms, 3817 Olive Street, Wednesday evening, January 18, 1905. President Flad presided. Thirty-five members and four guests were present.

The minutes of the 590th meeting were read and approved, and the minutes of the 382d meeting of the Executive Committee were read.

The following applications for membership were read and referred to the Executive Committee: Herbert I. Finch, Stanley H. Moore.

The following were elected to membership in the Club: James Adkins, Jr., Archibald L. Anderson, Gurdon Gilmore Black, James T. Dodds, William August Hoffman, Arthur I. Jacobs, Cloyd Marshall, Wilfred Van Ness Powelson, Charles Winfield Trowbridge.

The Secretary reported that notice had been received of the death of Mr. M. L. Mitchell, a member of the Club, on September 27, 1904.

Mr. W. G. Brenneke, Chairman of the Committee on New Quarters, presented the final report of the Committee. The report was received and ordered filed, and the Committee discharged.

The President appointed the following as the Entertainment Committee for the year 1905: W. G. Brenneke, R. S. Colnon, C. D. Purdon, Richard McCulloch, Gerard Swope.

Mr. Daniel Breck, Chief Engineer of the Terminal Railroad Association of St. Louis, presented a very interesting paper upon "Recent Terminal Improvements in St. Louis." After discussion by Messrs. Helm, Winn, Moreno, Flad and Breck, Mr. A. P. Greensfelder presented a supplementary paper of interest upon "Some Details of Reconstruction Work at the Union Station." After brief discussion the Club adjourned, as the hour was late.

R. H. FERNALD, *Secretary.*

592D MEETING, ST. LOUIS, FEBRUARY 1, 1905.—Held at the Club rooms, 3817 Olive Street, Wednesday evening, February 1, 1905, President Flad presiding. There were present twenty-five members and four guests.

The minutes of the 591st meeting were read and approved, and the minutes of the 383d meeting of the Executive Committee were read.

Applications for membership in the Club were read from Robert E. Adrean, Baxter L. Brown, Edward L. Dillon, Wm. S. Henry, John B. Meyers and Frank W. Valliant.

Mr. Herbert I. Finch and Mr. Stanley H. Moore were elected members of the Club.

The paper of the evening upon "Inventions and Patents," by Professor J. H. Kinealy, was received with interest, and after brief discussion by Messrs. Flad and Moreno, the Club adjourned.

R. H. Fernald, *Secretary.*

593d Meeting, St. Louis, February 15th, 1905.—Held at the Club Rooms, 3817 Olive Street, Wednesday evening, February 15th, 1905, President Flad presiding. There were present thirty-four members and two guests.

The minutes of the 592d meeting were read and approved, and the minutes of the 384th meeting of the Executive Committee were read.

Applications for membership in the Club were read from George Waters Arnott, Wm. Ralph Bush, Wm. H. Elliot, Elmer C. Peper.

The following were elected to membership in the Club: Robert Enos Adrean, Baxter L. Brown, Edward L. Dillon, Wm. S. Henry, John B. Myers, Frank Worthington Valliant.

Owing to frequent absence from the city and pressure of business, Mr. H. H. Humphrey was unable to prepare his paper on "Industrial Electric Power Plants."

Prof. A. S. Langsdorf kindly came to the rescue and presented a paper on "The Regulation of Alternators."

Following the paper, Mr. E. W. Parker, Director of the U. S. Geological Survey Coal Testing Plant, at the World's Fair Grounds, made a few remarks regarding the progress of the work and the results secured.

Professor Langsdorf and Professor Fernald outlined briefly the arrangement of the engineering laboratories of Washington University.

The President announced as the paper for the meeting of March 1st, "Our Grade Crossing Problems," by Mr. Carl Gayler.

Adjourned. R. H. Fernald, *Secretary.*

Engineers' Club of Minneapolis.

179th Meeting, Minneapolis, Minn., February 13, 1905.—Called to order by President Avery, in the County Commissioners' Room. Minutes of the last meeting were read and approved. The following names were proposed for membership: E. D. Williams, mechanical engineer, 317 Hennepin avenue, Minneapolis; Ernest W. Langdon, architect, 312 10th avenue, South, Minneapolis; A. P. Melton, manufacturer, 601-7 Northwest Bl'd, Minneapolis.

The Secretary read a number of letters from Mr. Dexter Brackett regarding proposed changes in the rules governing the Board of Managers of the Association of Engineering Societies. A short discussion followed, resulting in the Chair appointing Mr. Tate and Mr. Rogers to confer with Representative Hoag as to what action should be taken about dues and membership.

Mr. Avery, retiring President, then spoke briefly, offering such suggestions regarding the future welfare of the Society as had occurred to him from his experience as President.

The Secretary submitted his report for the year as follows:

Annual Report of the Secretary.

The following report for the year of 1904, is submitted by the Secretary:

Seven meetings were held during the year, as follows:

172d Meeting, January 18th. Held in the County Commissioners' Room. Reports were made by various committees. New officers were elected for the ensuing year.

173d Meeting, February 29th. Held in the County Commissioners' Room. A paper was read by Mr. Francis Henry on "Rice Culture in Texas and Louisiana." Prof. F. H. Bass read a paper on "The Relation of the Engineer to the Public Health."

174th Meeting, March 28th. Held in the County Commissioners' Room. A paper was read by Geo. H. Maxwell, of Chicago, on "The Engineering Problems of the West, or What the West Offers to the Engineer."

175th Meeting, June 4th. By invitation of the Minneapolis Steel & Machinery Co., a visit of inspection was made to their plant.

176th Meeting, October 10th. Held in the County Commissioners' Room. Papers were given by the following gentlemen concerning our city water supply: Andrew Rinker, Dr. J. Frank Corbett, A. D. Meeds and F. W. Cappelen.

177th Meeting, October 31st. Held in the Teachers' Assembly Room at the City Hall. The papers of the evening were devoted to concrete-steel construction, as follows: "The International System," by F. W. Graham; "The Turner System," by C. A. P. Turner; "The Brayton System," by Louis F. Brayton.

178th Meeting, January 24, 1905. Held on the fourth floor of the Court House, in conjunction with the Northwestern Concrete Manufacturers' Association convention. Mr. Richard L. Humphrey, of Philadelphia, delivered a lecture on "Cement."

Three papers given before the Club have been published in the Journal, and at least one other is now being gotten ready for publication.

The membership of the Club during the year has remained about the same. No new members have been taken in; two or three have been dropped on account of non-payment of dues, or their present addresses being unknown.

The writer has now had the honor of this office for two years, and would request that the honors and privileges of the office should now be given another.

Respectfully submitted.

J. B. Gilman, *Secretary.*

The following statement of the receipts and expenditures of the Club for the year of 1904 is submitted by the Treasurer:

RECEIPTS.

Cash on hand when accounts were last audited	$69.60	
Dues of 58 members for 1904	174.00	
Dues of 9 members for 1905	27.00	
Received from sale of magazines	33.50	
		$304.10

EXPENDITURES.

Stamped envelopes	$10.60	
Stenographic Work	5.75	
Association Journal	143.30	
Printing cards	28.50	
Engrossing	8.08	
Printing membership certificates	4.50	
Printing magazine catalogue	23.00	
Lantern slides illustrating papers	21.00	
Postage, stationery, etc.	4.50	
		249.23
Balance on hand		$54.87

Respectfully submitted,

B. H. Durham, *Treasurer.*

J. M. Tate, Chairman of Committee on Exhibits for the St. Louis Fair, made a final report that everything had been finished up satisfactorily and without any expense to the Club. Committee was discharged.

The election of officers for the ensuing year resulted as follows:

President—E. P. Burch.

Secretary—H. A. Rogers.

Treasurer—O. P. Bailey.

Librarian—W. W. Redfield.

Representative to the Association of Engineering Societies—H. B. Avery.

Finance Committee—C. S. Pillsbury and J. M. Tate.

E. P. Burch, incoming President, continued the committee appointed at a former meeting to make arrangements for a banquet. He also appointed the following committees:

O. P. Bailey, on Membership Card.

N. P. Cowles, on Badge.

H. A. Rogers, on Advertising.

The meeting then adjourned.

J. B. Gilman, *Secretary.*

Montana Society of Engineers.

The eighteenth annual meeting of the Montana Society of Engineers was held in Butte, Friday and Saturday, January 13 and 14, 1905, with the largest attendance of members within the history of the Society. Friday was devoted to visits to various points of interest about this mining region. In the forenoon a trip was made to Walkerville and an examination made, through the courtesy of Messrs. Wisner & Humphrey, of the plant of the Montana Zinc Co., recently built to reduce the refractory zinc ores of this section. After lunch the members were the guests of Mr. Thomas Bryant, Superintendent of the Original Mining Co., and were given a trip through the West Stewart Mine and an opportunity to see a very economical method of handling and framing mine timbers. Later in the day a call was made at the Pittsmont Smelter, where the members were favored with a fine lunch and given permission to examine fully the new process of ore

reduction of the first smelter of the kind erected in Butte. Every kindness was shown the members by the manager's corps of assistants, and a late departure was made for headquarters, with the only regret that Manager Baggeley of the Smelter was too ill to meet the members of the Society. In the evening the visiting members were the guests of the Butte members at the Broadway Theater and after the play were served with a collation at the headquarters of the Society, Room No. 25 Lewisohn Building. Saturday was devoted strictly to business. The meeting was called to order at 10 o'clock, with President Moulthrop in the chair, and a quorum present. The minutes of the previous meeting were read and approved. The Secretary presented the applications of Messrs. J. R. Wharton, D. C. Bard and Alvin O. Greeson for membership in the Society, and on approval the ballots were ordered sent out. Mr. Geo. B. Couper was elected to membership by a unanimous ballot. The ballots for the new officers for the ensuing year were submitted to Tellers Carroll and Dunshee, who reported the result of the election as follows: Ernest W. King, President; Bertram H. Dunshee, First Vice-President; Edward C. Kinney, Second Vice-President; Clinton H. Moore, Secretary and Librarian; Samuel Barker, Jr., Treasurer; Robert A. McArthur, Trustee. President Moulthrop declared the above-named persons elected to their various offices, and in a neat speech introduced President King, who thanked the Society for the honor conferred upon him and then proceeded with the next order. The report of the Committee on Resolutions on the death of Wm. Munroe was read and adopted. The Secretary's and Treasurer's reports for the past year were read by those officers and referred to the proper committee. Communications were read by the Secretary from Messrs. C. M. Thorpe, J. W. Neill and President N. R. Leonard. The one from President Leonard had special reference to the appointment of a State Geologist. His communication was referred to a Committee, to report in the afternoon. The Secretary then read a new set of rules of the Association of Engineering Societies, under discussion by that organization, and after a lengthy discussion by the members present it was voted that the question of the Society remaining in the Association of Engineering Societies be made a special order of business at our March meeting and the Secretary be directed to invite written discussions from all active members of the Society. The Committee appointed on a communication from Mr. A. H. Wethey asked for further time to consider the matter and it was granted. Mr. Carroll moved the thanks of the Society to all parties whose favors had contributed to make the meeting a success, and after the present of a fine picture by Mr. E. C. Kinney, the session was adjourned to 1.30 P.M. The afternoon session was called to order by President King, and retiring President Moulthrop favored the Society with an address. Mr. Moulthrop was followed by Mr. E. J. Strasburger, with a thesis entitled, "The Central & Cerre de Pasco Ry. of Peru." Mr. Carroll read a paper written by himself and Mr. Emil Starz, on "Sulphate of Copper" as a water purifier, and Professor C. H. Bowman gave a dissertation on "Stresses in a Gallows Frame." The last paper was a discussion of U. S. Mining Laws by C. W. Goodale, and after its reading it was referred to a committee to take up the question and petition the government to make such change. Mr. Goodale's paper brought forth remarks of interest from many members. Mr. Geo. Couper presented a communication from the Engineers' Club of Bozeman, and the Secretary read

one from Great Falls relative to the marking the "Trail of Lewis and Clarke" by suitable monuments. The committee on the matter of a State Geologist reported in favor of the same, and the Secretary was instructed to mail a copy of the proposed bill to various members of the State Legislature now in session. In the evening a banquet at the Hotel Finlen closed the annual session.

CLINTON H. MOORE, *Secretary.*

THE regular monthly meeting of the Society was held in the Society Room, 16 Leyson Block, on Saturday evening, February 11, 1905, with President King presiding, and a large membership in attendance. The minutes of the annual meeting were read and approved. Messrs. J. R. Wharton, D. C. Bard and Alvin O. Greeson were elected to membership in the Society, and Chas. M. Allen was reinstated. The applications of Frank Hayes Keller, Robert Kilgore Humphrey, Howard Donald McLeod and Chas. William Leimer to become members of the Society were read by the Secretary, and after approval it was ordered that ballots be sent out. Mr. Joseph H. Harper presented his views on the proposed changes in U. S. Mining Laws in a written paper, and at the close of his remarks a lengthy discussion on the part of a majority of the members present followed. At length it was decided that a continuation of the subject of mining law changes and legislation be made the leading topic for the March meeting. The Society then adjourned.

CLINTON H. MOORE, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

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PROCEEDINGS.

Technical Society of the Pacific Coast.

REGULAR MEETING, SAN FRANCISCO, CAL., NOVEMBER 4, 1904.—This meeting was held for the purpose of discussing informally the autumnal meeting to be held December 1, 2 and 3, 1904, and no other business was transacted than that directly connected with this subject.

The discussions were entirely informal, and the meeting adjourned to be called December 1st for the transaction of business and for the reading of the papers prepared for the autumnal meeting.

OTTO VON GELDERN, *Secretary.*

FALL MEETING, DECEMBER 1, 2, AND 3, 1904.

DECEMBER 1ST.—Called to order at 8.30 o'clock P.M., by President George W. Dickie, who welcomed the members and guests by an introductory address.

In the order of business the following members were appointed a Nominating Committee to select a ticket of officers for the ensuing year: Marsden Manson, F. C. Herrmann, L. S. Griswold, Adolph Lietz and Hermann Kower.

Mr. W. A. Doble read a paper, written by Robert McF. Doble, illustrated by numerous lantern slides, on the subject of the "Development of Water Power and its Electrical Transmission," which was in part a history of the various plants in operation in California to-day.

The meeting thereupon adjourned to be called at 2 P.M. on Friday, December 2d.

DECEMBER 2D, AFTERNOON SESSION.—Called to order at 2 o'clock P.M., by President Dickie.

The paper proposed by Mr. Geo. W. Nichols on the subject of "Water Power and Electricity in California" was omitted, the author having been compelled to remain out of town.

Mr. James C. Bennett thereupon read a paper in which he stated his views, from the standpoint of the consumer, as to the advantages and disadvantages of electric light and power made applicable, in his case, to the many mechanical services required of it at the Selby Smelting Works. This paper proved of considerable interest and was discussed by R. W. Myers and F. P. Medina.

Mr. Frank P. Medina read a paper entitled "Engineering and the Law," a subject that caused a discussion of some length.

Meeting adjourned.

December 2d, Evening Session.—Called to order at 8.30 o'clock p.m., by Vice-President Franklin Riffle.

The first paper of the evening was read by Mr. Edward T. Hewitt, who chose, for his subject, "Trade Schools and their Application," going exhaustively into the phases of the modern training of youth on the principle of producing men fitted for the practical pursuits of life.

This paper was discussed, from various points of view, by Mr. Geo. W. Dickie, Professor C. B. Wing, Mr. Orion Brooks, Mr. Marsden Manson, by the chief instructor of the Drawing Department of the Humboldt Evening School, by Professor Durand, of Stanford University, and by the author, Mr. Hewitt, who defended his position that the schools filled a requirement that had long been felt, that they were successful wherever introduced, and that they are now an established fact, until something still better can be found to replace them.

A paper by Mr. John Richards, past President of the Society, entitled "Phenomena of Machine Operation," was read by the Secretary. The subject was afterward discussed by Mr. Thomas Morrin and by Professor Durand, of Stanford University.

Meeting adjourned.

December 3d, Afternoon Session.—Called to order at 2 o'clock p.m., by Vice-President Franklin Riffle.

The following papers were read by their respective authors and discussed by attending members:

"Durability of the Materials of Masonry Used in San Francisco," by Marsden Manson.

"Collimating and Azimuthing a Modern Gun," by Otto von Geldern.

Meeting adjourned.

December 3d, Evening Session.—A banquet was given by the Society at the Occidental Hotel, and was largely attended by the members and their ladies.

Opening Remarks by the President, G. W. Dickie.

It is very pleasant for us hard workers to sit down to dinner together on a Saturday night. We technical men have much in common that draws us together for the reading and discussion of papers relating to our work, but as a rule we fail in social accomplishments. Even on a night like this, with ladies present, we take our dinner rather seriously. This is a part of our training that has been sadly neglected.

The technical man needs a broader education than he generally succeeds in getting. A steady practice of our profession tends to narrow the man. He lives and moves and has his being in cast iron and steel, stone masonry and earth dams, and often other kinds of dam(n)s that we cannot indulge in to-night, so that his whole life gets set into a rigid mold, out of which he cannot extricate himself.

A dear old engineer friend of mine, who stands high in his profession, has allowed himself to fall into very profane habits of speech. One day, I tried to reason with him about it, showing how terribly handicapped he was by his unfortunate habit. "I know it," he said, "better than you can

tell me. If I had only learned poetry when young, as you did, it would have been better for me. Poetry is far more effective than swearing."

My friend was quite right about this. I remember, when serving my apprenticeship in the locomotive shops of the North British Railway (I would not like to say, in the presence of so many fair ladies, how long ago this might be, but last century was just about in its prime then), I was at the time working with a man named Robert Sproule under an engine. I was holding up the eccentric rod for him to put in the link pin, when an inspiration came on him and he started in to recite from "Marmion":

"The war that for a space did fail,
Now trebly thundering, swelled the gale,
And Stanley was the cry."

Just at that point the foreman stopped him, with the statement that he was of no use except for a play-actor, and he thought of giving him an opportunity to follow that profession. Poor Robert was stunned for an instant, but soon recovered, and catching the eye of the foreman, remarked quietly, "That is very true, Mr. Brown, but—

"Full many a gem of purest ray serene,
The dark, unfathomed caves of Ocean bear;
Full many a flower is born to blush unseen
And waste its sweetness on the desert air."

The poor foreman was completely discomfited and Robert remained at his work, victorious. Swearing is not in it with poetry.

I hope such meetings will help us in softening the hard spots in our professional experience, rendering us more fit to take our places in the best society of men and women, which, after all, is the better part of life.

I believe that we shall have our next dinner somewhere else than in San Francisco. I do not know where that may be, but somehow our spring meeting next year will, I hope, be held in some other town of the Pacific Coast.

It is very pleasant to look around this table and see so many kind people, whose faces call up memories of other faces that are not with us. Some are done with all work, but their memory lingers with us and we think of them to-night; others are kept from us by business reasons, and some are in other lands. We think of them all at this time, and I will call on Mr. Marsden Manson to speak to us on their behalf.

"Our Absent Friends," By Marsden Manson.

Mr. Marsden Manson, in responding to the toast "Our Absent Friends," referred to the following members of the Society, and spoke feelingly of each one, relating, in an interesting manner, the causes that had taken them all over the world, to work, through their profession, in the interests of humanity:

H. C. Behr, Consulting Engineer in Johannesburg, South Africa.

A. B. Bowers, traveling in the interest of his dredging machines.

C. E. Grunsky, Isthmian Canal Commissioner, in Washington or Panama.

J. B. Hobson, Mining Engineer in British Columbia.

Chas. F. Hoffmann, on an extensive trip in the interest of mining.

D. E. Hughes, in charge of fortification works at San Diego, Cal.

C. H. Kluegel, Railway Engineer in Hawaii.

Charles List, Resident Engineer in Cristobal, Panama.

Frederick Hellmann, Mining Engineer, Boksburg, South Africa.

Jas. D. Schuyler, Consulting Engineer, Los Angeles, Cal.

Wm. P. Smith, engaged in various engineering enterprises in Chicago, Ill.

The members and friends present drank to the health and prosperity of each one named.

"The American Society of Civil Engineers," By C. E. Moore.

Although I see before me other members of the American Society who might more appropriately reply on its behalf, it is fitting that these two subjects, "The Civil Engineer" and "The American Society," should be combined, for, although the local Societies have filled their place, yet the American Society has largely stood for American engineering since its organization. It numbered, among its early members, the pioneers in the great material development of the country.

With the rapid growth of modern applied science, engineering has become to a great degree specialized, and we have the Societies of Mechanical, Mining and Electrical Engineering, the Maintenance of Way Association, the Waterworks Associations, and others. These were all, or nearly all, preceded by the American Society of Civil Engineers, and possibly they may be regarded, to a great extent, as outgrowths from it, just as the various branches have grown out of civil engineering.

The civil engineer finds it necessary to keep in touch with all these, more or less, according to his work, and it is hardly possible to put civil engineering in a division by itself, and say, "here is civil engineering," here (in another division) is mechanical engineering, etc., inasmuch as civil engineering embraces them all to a certain extent.

Now, in this connection, there are two or three thoughts which I shall endeavor briefly to bring to your attention.

As we look over the field of past accomplishment, and the great progress that has been made, we are apt to lose sight of the steps which have made such progress possible.

It is hard to realize that about 200 years ago it was a common practice, in certain European cities, to throw slops through the open windows into the streets, so imperfect were the sanitary arrangements of those days; that there was an ordinance in the city of Edinburgh, for instance, requiring householders to call out a warning to the people who might be passing. It is hard to realize that, at a much more recent date, when it was proposed to construct a railroad from Albany to Schenectady, in the State Legislature at Albany there was great ridicule over the possibility, which was claimed by the projectors, of running cars at the rate of 10 miles an hour over that road. The possibility of attaining such speeds with this new contrivance was a subject of considerable merriment among these wise legislators.

Right here is the first thought which I would make prominent. It is not popular, and it may at first give some of you a mild shock that I should

so far depart from the usual laudatory style of treating this subject as to give it utterance. It is none the less true, as I think I can prove to you. The thought is this—"that one of the most potent factors in the progress of engineering has been disaster." My proof of this must be largely drawn from personal experience, inasmuch as I had its truth brought home to me some years ago with such emphasis that it has ever remained. Therefore, you will pardon me, I know, if what follows just here tinges somewhat of the personal.

Many of our great railroad systems grew up by combining separate roads, built under separate management, by various companies, and various engineers. These separate properties were later taken up by one company and welded into one system. As regards structures particularly, these early engineers had been working largely in untried fields. This was a transition period, not only in the operation of railroads, but very particularly in bridge construction. In this transition period, it was my fortune to be connected, about 1880 to 1885, with one of the great systems of the Middle States. New roads were being taken into the system, and made a part of through lines. This was the case not only in this particular system, but in others.

On these separate roads were many styles of bridge construction. To-day some of them would be esteemed curiosities. When they were put under a system of rigid inspection, for heavy train loads and rapid speeds, grave faults were often discovered. In that transition period there were many disasters, one of which you will remember as that of Ashtabula, following which, Mr. Collins, the Chief Engineer of the Lake Shore Road, shot himself while sitting at his desk in Buffalo. I am thankful to say that personally I never came in touch with such disasters as that one; yet it came in my way, about this time, to fish some spans out of the river into which they had fallen, and to have broken up at the shops the large castings used for compression members. Many of these large castings were very defective. I have here some photographs taken at that time showing some of the faults found.

On that road and at that time, we learned the dangers attending the use of cast iron for such purposes. Many others were learning it at the same time. It was evident that many of the failures had come from that cause.

The lessons were costly, but they had their influence in the adaptation of rolled shapes for compression members, and finally in the cheapening of steel processes, which now make it possible to use steel for all such purposes.

Now, leaving this somewhat gruesome branch of the subject, I come to the second thought, and that is as to the kind of men who have made up the great body of engineers and of the American Society. Whatever may be our views of life, we must recognize, I think, that the great object, in our being here at all, is the development of character. In this connection, I consider the engineer to be most fortunate. He deals with the laws of nature. He cannot ignore these laws, or evade them. He must meet them fairly and squarely, and with honesty of purpose. He must be open to conviction, and be ready and willing to modify old ideas and adopt new ones. This all tends to the development of an honest and generous nature.

If we do not get this, we have missed the point of our training.

And here I desire to say that, having had quite an extensive acquaintance with engineers, I have all my life found them, as a class, developing those very traits. As a class, they are free from petty selfishness; as a class, you may safely trust them with your private or public interests, feeling tolerably

certain that no mean advantage is to be taken, and no important duty neglected. I do not know whether my acquaintance with engineers has been especially fortunate, but I must say that in my experience this is the kind of men made by such training, and I would not limit this statement to engineers proper, but would apply it to all practical technical men—to all who are dealing directly with the laws of nature.

"The American Navy and the Shipbuilder," By John G. Tawresey, Naval Constructor, U. S. Navy.

I have enjoyed very much the privilege of attending some of your meetings, and I take pleasure in being here to-night. Navy men are not speakers. Some of them, shining examples, have got into trouble by talking too much. Your President has mentioned some of the difficulties in building ships for the United States Navy. There are difficulties, but we do not wish to consider them to-night.

It occurs to me that technical people are much more conservative than they are generally represented. The new design and the new scheme are not absolutely new and revolutionary; they are only the old principles carried a step farther; the new scheme is based on something that has gone before. Very few entirely new designs are successful. In the navy we are so conservative that we go on using old methods even when we know that they are wrong, for fear the new might not be any better.

The relation between the navy and technical engineers is close. The designs for the splendid modern war ships have grown from and are based on the general fund of information, experiment and experience, to which all technical men are contributing, and in that sense all have shared in making such ships possible and successful, whether engaged directly in naval architecture or in the other branches of the engineering profession, which all contribute indirectly to it. No one man can claim that he did it; neither the naval officer nor the shipbuilder can take all the credit, for every part of the design is based on something that has been done before.

It is something to be thankful for that the new navy has been produced and has been successful in general, and that no ship has been a complete failure. The ships built on this coast have been pre-eminently successful. All of you can feel that you have contributed something toward producing them. We should all be proud, as I am proud, of the new navy and the yards in which it has been built, not the least of which is the one in your own city.

"American Society of Mechanical Engineers," By Thomas Morrin.

As a member of the American Society of Mechanical Engineers, and as a practical engineer for over thirty years on this coast, I can say that it has been my pleasure and duty to be connected with some of the important work carried on upon the coast. I have witnessed a great deal of the practical improvements in nearly all of the engineering lines, embracing mining, marine, hydraulic and electrical engineering.

When electric light and power came to the front, a few years ago, it attracted the attention of the whole world and revolutionized the mechanical standards of every country. It has been the greatest mechanical developer since the time of Watt.

The engineering profession has attracted the attention of the brightest of our young men, and the schools and colleges of the country are meeting the demand for technical education in a most satisfactory manner. Professor Sweet said to me, a few years ago, that it was particularly unfortunate that so many of these young men were induced to leave the practical for commercial pursuits, solely for monetary reasons. It matters but little, however, which of the engineering branches the young man selects for his vocation; some time in his career, he will come to the mechanical engineer for assistance, as there are few important works undertaken which do not require the mechanical engineer in some part of the equipment.

Electricity has done wonders in developing the latent energy of our men and of our country. Our worthy President has shown much of this in the war ships he has built, and the mechanics he has turned out at the Union Iron Works.

"The Technical Training of Youth," By Edward T. Hewitt.

Mr. Chairman, ladies and gentlemen:—Having been asked to address the Technical Society and its many friends gathered here this evening, on the subject of "The Polytechnical Training of Our Youth," I wish to say that I appreciate the honor. Instead of making an address, I shall confine myself to a few brief remarks. The subject apparently is a very complex one, but by analyzing it we may determine its value. Now all education, at every stage of life, comprehends two processes—the training of powers and the acquisition of knowledge. Childhood and youth are the times for acquiring new mental processes and functions, and for exercising and strengthening the memory. The important thing in childhood is, therefore, to train the child in as large a variety of mental processes as possible and to establish many useful mental habits.

Now, I can only sketch the barest outline as to how education is to deal with these highly complex factors. Let us note one aspect of the relation between science and occupation. Science teaches us to think in a clear, logical and systematic way, putting our conclusions to the test of experiment. All theory, all knowledge, all the broad groups of sciences, originally sprang from the experience gathered by man from one or other of his numerous occupations. Thinking has arisen from doing. Science ultimately sprang from the desire and efforts of men to increase their skill in their occupations by understanding the eternal principles that underlie all dealing with nature. If science sprung from occupations, she has repaid the debt, both by rendering those who follow her teaching more skilled in their occupations and by actually giving rise, through her discoveries, to absolutely new types of occupations.

Observing the men engaged in these occupations, we find different grades of skill. One kind is the gift of nature, innate. Another kind of skill has been developed by routine work and constant repetition, while another kind is the product of definite scientific training.

The harmonious combination of theory and practice is shown in a very high degree in the lives and work of great engineers. In the days of Stephenson, Watt and Fairbairn, technical schools were practically unknown. To-day education is the watchword; conditions are such that even the common laborer, digging a trench, has to know how to do his work expedi-

tiously and in a workmanlike manner. In planning for the proper education of youth, we are forced to consider certain present conditions, but the greater idea is to lay, at the same time, the foundations of an educational edifice that will be utilized by the generations yet to come.

College men are entering all walks of life. Formerly the professions were the only fields of endeavor considered by them. They now find that their training eminently fits them for business careers.

The poor inhabitants of certain parts of our large cities were at one time left to themselves; charitable institutions were looked upon to help them in their many temporary necessities. This is changing. Manual training, industrial education, domestic science and art work are being brought into the schools. For these poor people life is now beginning to assume a different aspect. We are helping them in a better way when we teach them to help themselves. Gradually you will see a change in their home surroundings. A study of the work being accomplished by the social settlements, parental schools, juvenile courts, manual training and trade schools will convince you that these institutions are an effective power for good. These schools are not limited to the poor only. All phases of society desire education. Youth is the time for study, later life for the application of knowledge obtained. The many schools of industrial training, that are open to the youth of this and other countries, are a reflex of the exacting requirements of modern times. All that the school can do is to give our young people such a systematic training that they may successfully carry out their life's purpose.

"Electrical Development," by Orion Brooks.

I feel highly honored at being thought capable of doing justice to the subject "Electrical Development," but I fear that I shall disappoint you. It is true that I have seen the rise of electrical industries, from 1867, when four or five men, in a little shop in this city, did all the manufacturing and repairing of electrical apparatus for the whole Pacific Coast, until, about 10 years later, I knew nearly all the persons engaged in electrical pursuits in California (I don't know all such now). I have seen the growth of electrical engineering until, like a landslide, it has overwhelmed us, and no one person can hope to know personally more than a very few of the men engaged in it. My chief reason for being with you this evening is that I may see some faces new to me, but with a fellow-feeling.

Few can realize the magnitude of the electrical industry to-day, even on this coast, where, as the editor of one of the leading electrical papers of the East said, "We do things, while they are talking about them." It is a way Californians have. I may be pardoned for mentioning a few San Francisco pioneers who did some electrical things, and whose names come to mind—Lundberg, Field, Ladd, Gamble, Greenwood, Sabin, Roe, Cornwall. At one time, late in the seventies, I started a scrap-book, for the collection of notices of new electrical enterprises, but the number grew so rapidly that I gave it up as a waste of time (I had work to do). It seems but yesterday that we had only the telegraph and a few electric bells. Next came a few electric lights and an electric street railroad. To-day there is more capital invested and more people employed in electrical enterprises than a good mathematician can compute. The Sacramento and San Joaquin valleys are calling for a network of electric railways. Electric lights are in every hamlet and farm-

house, supplied from the watersheds of the Sierras. The steam engineer and the horse are looking about, bewildered, for a soft spot to fall on. We even hear propositions to operate trunk lines of railway by electric power, and to-morrow—?

What is this thing we call electricity? The question is old and threadbare, but is being repeated again and again; and though, occasionally, someone seems to be almost on the point of drawing aside the curtain, the scene shifts and we are little if any wiser than before. The subject is too broad and deep for an after-dinner speech. What subject is larger?

I am glad to be with you to-night, and will not weary you further. Good evening.

"Our New Territory, Hawaii," By M. M. O'Shaughnessy.

Looking at a map of the world, the islands of Hawaii do not occupy much space—in fact, one would need a magnifying glass to recognize many of them—yet problems of great interest have been there thrashed out, until it can be truly said that Hawaii has the best developed irrigation system in the world, and much of this is due to members of this Society who have lent their services to its development in the past. Among others, I may mention the names of Mr. Schuyler and the late Mr. Allardt, who first reported on the Oahu artesian supply, fifteen years ago. Mr. Kluegel has also been closely identified with engineering projects for the last 20 years.

The main industry of Hawaii is sugar, of which it will raise this year about 400,000 tons, worth $32,00,000, from an arable area of 150,000 acres, or about the size of one county in the State of California. This is about double the value of the wheat crop of the whole State.

Too much praise cannot be given to the white race in the tropics for developing a non-productive country of 30 years ago to its present advanced stage of prosperity.

The islands are very steep, having mountains in the center, from 3000 to 10,000 feet high, with all the arable land near the seashore, below an elevation of 500 feet.

The trade winds from the ocean make the rainfall very local in its character, one side of an island, such as Maui, having over 300 inches average annual rainfall, while, 30 miles distant on the same island, the precipitation is only 10 inches.

The work with which I have been specially identified consisted in taking water from belts of heavy precipitation to the dry and warm ones, suitable for sugar-cane growing. Over 25 miles of tunnel aqueduct, carrying from 30,000,000 to 90,000,000 gallons per 24 hours, have been constructed in the past 2 years, to carry water from the mountain sections to the cane land belt.

At least eight plantations have daily water supplies, from pumps and gravity, of 60,000,000 gallons each, while the daily consumption of San Francisco is only 30,000,000 gallons, which will give you a conception of the magnitude of the water development in Hawaii.

There are about 60 plantations, owned by private corporations, engaged in the sugar business and each has its separate water supply, its transportation system for hauling cane to the mill, and its sugar factory, nearly all of which are the product of the machine shops of the mainland.

Hawaii is proverbially hospitable, and, should our Society decide to

hold a meeting under its balmy semi-tropic influence, I can confidently predict a generous and cordial welcome from all the people of Honolulu and the islands, whose motto is always "aloha," or welcome to the stranger.

"THE ENGINEER'S HOLIDAY," BY A. T. HERMANN.

This is surely the holiday for the engineers, and I am delighted to see it so well attended by my fellow-craftsmen and many of their wives and daughters. My son, I am proud to say, was smart enough to bring his wife along, and if I had but known what a fine company I was to meet here, I should have brought my wife also.

In years gone by, when friend von Geldern sent me the usual invitations, I could not see how I could possibly spare the time for any holiday, be it ever so short, for we—we—the engineers of California—were busy and hard at work, building up this magnificent State, planning its grand improvements, developing its resources; in fine, making it what you, my younger friends and classmates, see it to-day.

And it is good to look at, this grand California of ours, especially when you have known it in its nearly original state, and know that you have honestly helped to make it what it is. Look around: Is there anything more beautiful than this incomparable Bay of San Francisco, with the queen of the Pacific holding court and revelry at the entrance, commanding and absorbing the trade of the vast Pacific, and enriching her people beyond measure? with the shores of the bay dotted, from one end to the other, with flourishing cities, towns, villages, factories and villas without number, and lined in every direction by the steel bands that span the continent and connect us with the East, the scream of the iron horse forever intermingling with the roaring whistle of the palatial ferries, which, day and night, serve unceasingly in the immense traffic and travel of our people?

Truly, California is a great State; her people are well off, bountifully provided with all that man craves, blessed by the finest climate of the world. They should be proud of their magnificent State and proud of their achievements and of the State's unprecedented development.

And we—we engineers—know that we have done our share, nay more than our share, of this good work, and hence we deserve, fully deserve, this, our annual, our only, holiday. Hence let us enjoy it to the fullest measure, and never again begrudge the time spent for it.

And when it is done—to-morrow—let us return to our usual work; let us again give our best thoughts, our best energies, to the development of our beloved State; let us be true to the grand principles and aims of our profession; and, when the last hour comes, when our individual work is done, let us look fearlessly into the face of the great unknown, and leave our work to our younger successors. Then, let us lie down to the last rest, the final holiday of the engineer, rocked to the sleep that knows no awaking, by the lullaby of the waves of the grand Pacific.

The autumnal meeting of the Technical Society was declared adjourned by President Dickie, who announced that the next meeting would be held in the spring of 1905, and he also expressed the sincere wish to meet each and every one again in good health and spirits on the next occasion.

OTTO VON GELDERN, *Secretary*.

Regular Meeting, San Francisco, Cal., January 6, 1905.—Called to order at 8.30 o'clock p.m., by Vice-President Franklin Riffle.

The minutes of the autumnal meeting, of each session in regular order, were read and approved.

The Secretary referred to the fourth quarterly assessment payable to the Association of Engineering Societies, and read certain letters of Mr. John C. Trautwine, Jr., Secretary of the Association, in explanation of the high rate of one dollar for said quarter. The expenses of publication had increased considerably, and in order to meet them it was found necessary to make the fourth quarterly assessment for the year one dollar per member, making the total assessment, for 1904, two dollars and fifty cents, instead of two dollars, which had been the annual total since the year 1899, or making the average quarterly assessment, for 1904, 62½ cents instead of 50 cents.

Upon motion, the Treasurer was instructed to pay the bill, amounting to $172, expressing the hope that the old rates will hereafter prevail.

The Nominating Committee, appointed at the last regular meeting of December, reported, through its Chairman, Mr. Marsden Manson, that the following ticket for officers of the Society to serve during the year 1905 had been selected by unanimous choice:

For President—George W. Dickie.

For Vice-President—Franklin Riffle.

For Secretary—Otto von Geldern.

For Treasurer—Edward T. Schild.

For Directors—Hermann Barth, H. D. Connick, E. J. Molera, Carl Uhlig, George H. Wallis.

The Secretary was instructed to have the ticket printed and distributed for the annual meeting, January 20, 1905, when the election will take place. For tellers, the Chair appointed Mr. Adolf Lietz and Mr. H. A. Brigham.

The Secretary read the following communications—one a letter written by him to the Trustees of the Mechanics' Institute in reference to the library, and the other a report of the Library Committee of the Institute to the Trustees as a reply to the request made by the Technical Society:

"Technical Society of the Pacific Coast,
"San Francisco, October 10, 1904.

"To the Trustees of the Mechanics' Institute,
"San Francisco, Cal.

"*Sirs.*—At a meeting of the Technical Society, held October 7th, the matter of building up a good technical library, the need of which has frequently become manifest in San Francisco, was discussed, and the Secretary was instructed to communicate with your Board for the purpose of ascertaining your inclination toward a proposition that a committee from the Technical Society be permitted to act with your Library Committee in the matter of suggesting and arranging lists of such technical literature as that looked for by the profession constantly.

"Much of the engineering literature may be obtained in the shape of valuable reports that may be had for the mere asking, and in the transactions of the many societies, domestic and foreign, in which the most vital technical discussions are published.

"The Society thinks that the accession of a good engineering library and the setting aside of a certain space or room for that special purpose would be greatly appreciated, and that it could not fail to be of direct benefit. And, while the members of the Technical Society feel that the Trustees are doing all they can in the purchase of technical literature, the thought has suggested itself to them that you might perhaps look favorably upon any co-operation from the Technical Society to increase the scope and usefulness of the engineering library.

"If this should meet with your favor, we will suggest three names of men having special professional lines—that is, an expert electrical engineer, an expert mechanical and a civil engineer; these three men to be men of learning and book experience, whose advice in engineering literature could be counted upon as valuable.

"The underlying principle of this suggestion is to work toward a common interest, and that is to make the Mechanics' Library the only institution of its kind in the State where the mechanic may go and find, upon it shelves, the information required to increase his professional knowledge; and to make this information readily obtainable at some place or room of the Library specifically set aside for the purpose.

"All that the Technical Society wants to do is to help you in attaining this desirable end for the benefit of the Institute.

"Will you kindly let us hear your views on this subject, and whether this proposition is at all acceptable?

"Very truly yours,

"GEORGE W. DICKIE, *President,*
"per OTTO VON GELDERN, *Secretary.*"

"MECHANICS' INSTITUTE,
"SAN FRANCISCO, December 6, 1904.

"TO THE BOARD OF TRUSTEES,
"Mechanics' Institute.

"Your Committee on Library reports as follows:

"Your Library Committee has considered the communication received from the Technical Society of this city, dated October 10, 1904, through its Secretary, Mr. Otto von Geldern. Your Committee is in hearty accord with the views expressed by the Technical Society, and will be pleased in the future, as we have been in the past, to do all that is possible to bring about the desirable result suggested.

"The building up of a good technical library is our aim as well as it is our aim to build up a valuable library on other subjects.

"Your Committee appreciates keenly the value of the suggestion that a committee of three be formed of the members of the Technical Society with a view to giving us the benefit of their experience and acknowledged familiarity with the subject in hand.

"Such a committee could prepare, from time to time, a list of the books that should be purchased by the Institute on technological subjects; and such list, with their recommendations, might be presented, either through the committee itself or through its Secretary, to our Librarian, whose duty it is to prepare, for this Board, a list of all books that are considered of value to us and to all of our members. The Library Committee will at all

times give careful consideration to any suggestions from the committee of the Technical Society.

"The suggestion of the Technical Society, that the books pertaining to the engineering department be set aside and placed in some room, has already been carefully considered, and such books are now placed in the west wing of the second floor of the library, and further concentration of these books and such books as may be purchased in the future of a similar character will be considered and acted upon from time to time as the condition of the library may permit.

"At the present time, however, we do not see our way clear to make any radical change from the classification that we have at present.

"This matter, however, will be kept constantly in mind, and the suggestion of the Technical Society in this regard will be carried out as soon as it may be possible to do so.

"Your Committee further recommends that our Secretary be instructed to forward a copy of this report to the Technical Society through its Secretary for its information.

"Respectfully,
"(Signed) GEO. BEANSTON,
"LUTHER WAGONER,
Library Committee."

Mr. John B. Leonard referred to the present status of reinforced concrete construction in San Francisco, and spoke of the difficulty encountered in attempting to introduce it. He stated that many of the interested organizations and unions were antagonistic to this method of construction, and that only united action by a number of prominent societies, to offset the determined efforts of those opposed, could hold out any hope of winning the municipal government to a favorable consideration of this important subject.

He therefore moved that a committee of four be appointed to act in conjunction with similar committees from the San Francisco Chapter of the American Institute of Architects, and from the Contractors' Association, for the purpose of making a most serious, earnest and determined effort to effect such changes in the municipal building ordinances as to permit the erection of reinforced or steel-armored concrete walls, floors and partitions, in accordance with regulations to control and safeguard this economic and useful method of construction, which has been employed almost everywhere with great success, and which is retarded in this city by those who are directly interested in handling or manufacturing conventional materials in vogue.

The Society having expressed its hearty approval of taking a direct stand in this important matter, the Chairman appointed the following committee with full power to act with the other committees referred to by Mr. Leonard: Mr. Howard C. Holmes, Chairman; Mr. E. J. Molera, Mr. Maurice Couchot, Mr. Otto von Geldern.

The Secretary read a communication from Mr. Carlos List, giving an interesting account of the work in progress at Panama, and of the general conditions existing on the Isthmus, its political aspect, and present satisfactory state.

The following applications for membership were received and referred to the usual committee for approval:

FOR MEMBERS.

Arthur L. Adams, Consulting Engineer, San Francisco. Proposed by Lee S. Griswold, R. W. Myers, A. Ballantyne and Otto von Geldern.

Russell Chase, Civil Engineer, Southern Pacific Company. Proposed by H. A. Noble, H. I. Randall and Adolf Lietz.

FOR ASSOCIATE MEMBER.

William H. Alderson, Civil Engineer, graduate of University of California. Proposed by A. Ballantyne, R. W. Myers and Otto von Geldern.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Annual Meeting, San Francisco, January 20, 1905.—Called to order at 8.30 o'clock P.M., by Vice-President Franklin Riffle.

The tellers, appointed by the Chair at the last regular meeting, proceeded to open the ballots sent in for the annual election, and reported that fifty-eight votes had been cast and that all were in favor of the regular ticket as nominated.

The Chairman thereupon declared the following elected as officers and directors of the Technical Society of the Pacific Coast for the year 1905:

President—George W. Dickie.

Vice-President—Franklin Riffle.

Secretary—Otto von Geldern.

Treasurer—E. T. Schild.

Directors—Hermann Barth, H. D. Connick, E. J. Molera, Carl Uhlig, George H. Wallis.

The Secretary and Treasurer submitted their annual reports, which were read and ordered received and spread upon the minutes as a record of the Society. The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Annual Report of the Secretary for the Year 1904.

I have the honor to submit to the Society, through its Board of Directors, the following report, containing also that of the Treasurer, showing the condition of the Society on January 20, 1905, the date of the regular annual meeting:

The present total membership is 173, as follows:

Honorary members	2	Associates	19
Life members	3		
Members	149	Total	173

Of these 106 are resident members,
18 are resident associates, and
49 are non-resident members and associates.

Total, 173

Geographically distributed, there are, in:

San Francisco and vicinity	124	Washington	1
Northern California	15	Utah	1
Southern California	11	Kansas	1
Arizona	2		
Colorado	1	*Foreign.*	
District of Columbia	3	Africa	2
Hawaii	3	British Columbia	1
Illinois	1	Philippine Islands	1
Nevada	2	Panama	1
New York	2		
Oregon	1	Total	173

Professionally divided, there are:

Architects	10	Mechanical engineers	29
Builders	9	Military engineers	4
Chemists	2	Mining engineers	10
Civil engineers	76	Naval architects	1
Draughtsmen	4	University professors	5
Electrical engineers	5	Surveyors	8
Instrument makers	2		
Manufacturers	8	Total	173

Admissions in 1904:

By election—		By reinstatement—	
Members	15	Members	2
Associates	2	Total	19

Membership of the Society at the end of the year 1903:

Members and associates	158
Admissions in 1904	19
Total on membership list during the past year	177

Loss during the year 1904:

By death	1	Carried on membership list during 1904	177
By resignations	2	Loss	4
By suspension	1	Present membership	173
Total	4	Gain during 1904	15

Deaths during 1904:

C. J. Wheeler, Chemist, Pacific Portland Cement Co.

During the year the Society added to its membership the following:

By election:

MEMBERS.

Hugh C. Banks, Civil Engineer, San Francisco, Cal.
James C. Bennett, Mechanical Engineer, Oakland, Cal.
J. W. Carey, Architect, San Francisco, Cal.
W. J. Cuthbertson, Architect, San Francisco, Cal.

Robert McF. Doble, Civil Engineer, San Francisco, Cal.
Major C. E. Gillette, Military Engineer, San Francisco, Cal.
Lee S. Griswold, Civil Engineer, San Francisco, Cal.
Chas. E. Moore, Civil Engineer, Santa Clara, Cal.
Chas. H. Parcell, Civil Engineer, Sausalito, Cal.
Ralph E. Parker, Civil Engineer, San Francisco, Cal.
O. Holmer Phelps, Civil Engineer, San Francisco, Cal.
Robert Schorr, Mechanical Engineer, San Francisco, Cal.
C. H. Snyder, Civil Engineer, San Francisco, Cal.
Eugene T. Thurston, Civil Engineer, Oakland, Cal.
C. J. Wheeler, Chemist, Solano, Cal.

Associates.

Chas. S. Girvan, Manager Coal Co., San Francisco, Cal.
W. F. Roloff, Mining Superintendent, San Francisco, Cal.

By reinstatement:

Members.

Howard C. Holmes, Civil Engineer, San Francisco, Cal.
J. C. H. Stut, Mechanical Engineer, San Francisco, Cal.

Suspensions during the year 1904:
J. S. Walker, Perth, West Australia.

Honorary Members.

Colonel C. Seaforth Stewart, Washington, D. C.
Commodore Theodore D. Wilson, Washington, D. C.

Life Members.

George W. Dickie, San Francisco, Cal.
George H. Evans, Colorado.
E. J. Molera, San Francisco, Cal.

The following subjects were read and discussed officially during the year:

1. Radium and Radio-Activity, by Professor Edward Booth.
2. Synthetic Philosophy of Herbert Spencer, by Mr. F. P. Medina.
3. The Rise and Fall of the American Merchant Marine and Progress in Ship Design and Construction, by Mr. Joseph R. Oldham, N. A.
4. The Laying of the Pacific Commercial Cable, by Mr. Frank P. Medina.
5. Steam Turbine Motors, by Mr. John Richards.
6. Jet Pumps—New and Original Theoretical Developments, by Professor F. G. Hesse.
7. The Reclamation of a Mountain Swamp, by Mr. Marsden Manson.
8. Pipes and Joints for High Pressures, by Mr. Franklin Riffle.
9. Vertical Railway Curves, by Mr. H. I. Randall.
10. Armored Concrete Construction, by Mr. M. C. Couchot.
11. Skeleton Steel and Hollow Concrete Blocks Construction, by Mr. S. Giletti.

12. Experiments in Driving Piles for a Foundation with a Steam Hammer, by Mr. J. J. Welsh.

13. Consideration of Uplift as Affecting the Design of Masonry Dams, by Professor Chas. D. Marx.

14. Portland Cement Manufacture, by C. J. Wheeler.

15. Collection and Discussion of Material in County Highway Bridges, by Professor C. B. Wing.

16. The Removal of Shag Rock and Arch Rock in San Francisco Harbor, by Mr. H. L. Demeritt.

17. Pumice as a Building Material, by Mr. H. A. Diehl.

18. Hydro-Electric Power Development and Transmission in California, by Mr. Robert McF. Doble.

19. Electric Power Generation and Transmission from the Standpoint of the Consumer, by Mr. James C. Bennett.

20. Engineering and the Law, by Mr. Frank P. Medina.

21. Trade Schools, by Mr. Edward T. Hewitt.

22. Phenomena of Machine Operation, by Mr. John Richards.

23. Durability of the Materials of Masonry Used in San Francisco, by Mr. Marsden Manson.

24. Adjustment of Modern Armament, by Mr. Otto von Geldern.

Otto von Geldern, *Secretary.*

Report of the Treasurer for the Year 1904.

Cash in bank January 1, 1904	$649.89	
Cash on hand January 1, 1904	.21	
		$650.10
Received during the year to January 7, 1905		1,408.17
		$2,058.27
Expended during the year to January 7, 1905		$1,538.95
Cash in bank January 7, 1905	$474.52	
Cash on hand, January 7, 1905	44.80	
		519.32
		$2,058.27

The receipts are as follows:

Cash in bank January 1, 1904	$649.89	
Cash on hand January 1, 1904	.21	
		$650.10
Dues collected		960.67
Seventeen admission fees		85.00
Two diplomas		3.50
Banquet tickets collected		359.00
		$2,058.27

The expenditures are as follows:

Postage, stationery and mailing	$161.95
Printing and typewriting	220.10
Salary of Secretary	180.00
Collection percentage	79.40

Assessments to Association, 165 members at $2.50		$412.50
Dues to Mechanics' Institute		13.00
Booth lecture		10.00
Lantern illustration		10.00
Illustrations drawn for the spring meeting papers		25.00
Excursions, spring meeting, tug and car		48.00
Rent of Academy of Sciences Hall		20.00
Expenses of two banquets:		
Reserved plates and seats	$318.00	
Flowers for table	7.00	
Printing and stenographing	34.00	
		359.00
		$1,538.95
Cash in bank January 7, 1905	$474.52	
Cash on hand January 7, 1905	44.80	
		519.32
		$2,058.27

E. T. SCHILD, *Treasurer.*

SAN FRANCISCO, FEBRUARY 3, 1905.—A meeting of the Board of Directors in lieu of the regular meeting, which was omitted.

The Board was called to order by President Geo. W. Dickie.

The following committees were appointed:

Executive Committee—Vice-President Franklin Riffle and Directors E. J. Molera, Carl Uhlig and H. D. Connick.

Finance Committee—Directors George H. Wallis, Hermann Barth and E. T. Schild.

Members of the Board of Managers of the Association of Engineering Societies—President George W. Dickie and Secretary Otto Von Geldern.

The reports of the Secretary and Treasurer were read and approved.

The proposed spring meeting, to be held in May or June, was discussed at length by the Directors, and it was generally agreed to hold it in Portland, Oregon, during the Lewis and Clark Exposition. The Secretary was instructed to circulate preliminary notices of this coming event, and to call for professional papers to be read at the meeting.

The name of Past President John Richards was proposed for honorary membership in the Society and unanimously recommended for ballot, to take place at the March meeting.

The President agreed to deliver a popular lecture before the March meeting of the Society, entitled "The Man and the Ship," which the Secretary was instructed to announce in due time.

The salary of the Secretary and the collectors' percentages, at the usual rate, were ratified to remain as they were during the past year. The dues of the Secretary and Treasurer were also remitted, as has been the custom heretofore.

Meeting adjourned.

OTTO VON GELDERN, *Secretary.*

Regular Meeting, San Francisco, Cal., March 3, 1905.—A meeting of the Board of Directors was held preceding the meeting of the evening.

The reading of the minutes of the previous meeting was ordered omitted.

The Secretary announced the death of a member of the Technical Society, Mr. Burr Bassell, of Los Angeles. He referred to the prominent standing of Mr. Bassell as an engineer, and to the loss sustained by the Society through this untimely death.

The President appointed a committee, consisting of Mr. James D. Schuyler and the Secretary, to draw up suitable resolutions of respect in memory of the deceased member.

After a count of ballots, the President declared the following elections:

1. As honorary member—Past President John Richards.

2. As member—C. S. Freeland, assistant engineer, Southern Pacific Company.

The Secretary was instructed to notify these gentlemen of their election.

Mr. George W. Dickie, President, thereupon read a paper entitled "The Man and the Ship," which constituted the principal feature of the evening's interesting and instructive program.

Meeting adjourned.

Otto von Geldern, *Secretary.*

Boston Society of Civil Engineers.

Twenty-third Annual Dinner.

The twenty-third annual dinner of the Boston Society of Civil Engineers was held at the Hotel Vendome, Boston, Tuesday evening, February 28, 1905, and was attended by 126 members and guests. An informal reception was held at 6 and the dinner was served at 7 o'clock.

At the after-dinner speaking, the President of the Society, Frederick Brooks, acted as toastmaster, and introduced the following speakers: Mr. John C. Trautwine, Jr., Secretary of the Association of Engineering Societies; Rev. Charles F. Dole, President of the Twentieth Century Club; Commander Elliot Snow, Naval Constructor, U. S. N.; John W. Ellis, Director, American Society of Civil Engineers; Albert E. Leach, Analyst of the Massachusetts State Board of Health; Col. W. S. Stanton, U. S. A., Engineer Officer stationed at Boston; Lewis M. Hastings, Chairman, Sanitary Section of the Society; Desmond FitzGerald, Past President of the American Society of Civil Engineers; J. Emery Harriman, Jr., Civil Engineer, of Boston; and Henry Manley, Past President of the Society.

Among the other guests of the Society were: Walter B. Leach, President of the New England Railroad Club; Charles W. Parks, Civil Engineer at U. S. Navy Yard, Charlestown; Prof. George H. Barton, Massachusetts Institute of Technology; Judge James R. Dunbar, of Boston; Edward A. Church, and Fred E. Ellis. Music was furnished by the Albion Quartette of Boston.

Sanitary Section.

Boston, Mass., March 1, 1905.—The annual meeting of the Sanitary Section of the Boston Society of Civil Engineers was held at Tremont Temple, Wednesday, March 1, 1905, at 7.30 o'clock p. m., Vice-Chairman H. P. Eddy in the chair. Thirty-eight members and guests were present.

The annual report of the Executive Committee was read by the clerk, and a verbal report was made by the Chairman of the Committee on Uniform Statistics of Sewer Construction and Maintenance.

On motion of Mr. E. S. Larned, it was voted that a committee of three be appointed by the Chair to retire and bring in the names of three candidates for each office to be filled. The committee, consisting of E. S. Larned, I. T. Farnham and X. H. Goodnough, brought in the required nominations, and a ballot being taken, the following, receiving the highest number of votes, were declared elected:

Chairman—Harrison P. Eddy.

Vice-Chairman—Charles R. Felton.

Clerk—William S. Johnson.

Members of Executive Committee—Freeman C. Coffin, Leonard Metcalf and Arthur D. Marble.

Messrs. A. L. Fales and R. K. Porter were elected members of the Section.

A paper on "Timber Tunneling in Quicksand" was read by R. K. Porter, of Newton, and discussed by the members present.

William S. Johnson, *Clerk.*

Annual Report of the Executive Committee of the Sanitary Section.

Boston, March 1, 1905.

The Executive Committee is pleased to report that the first year of the Section has been one of great prosperity. The Section held its first meeting in February, 1904, 13 months ago, and it now has enrolled in its membership 149 persons, of whom 134 are also members of the Boston Society of Civil Engineers and 15 have membership in the Section only. During the 13 months there have been six meetings and one excursion.

The subjects discussed at the meetings and the principal speakers have been as follows:

February 3, 1904; special meeting; 120 persons present. Subject, "The Use of the Septic Tank in Sewage Disposal Works." Discussed by Frank A. Barbour, George E. Bolling, H. P. Eddy, X. H. Goodnough, H. W. Clark, L. P. Kinnicutt, R. W. Pratt, A. J. Gavett, C.-E. A. Winslow, F. Herbert Snow and D. C. Moriarta.

March 2, 1904; annual meeting; 88 persons present. Subject, "The Cleaning and Flushing of Sewers." Discussed by J. L. Woodfall, W. D. Hubbard, Charles R. Felton, Dana P. Libby, Bertram Brewer, W. C. Parmley, E. S. Dorr and F. H. Snow.

April 13, 1904; special meeting; 70 persons present. Subject, a continuation of the discussion begun at the previous meeting, by W. D. Hunter, H. P. Eddy, George A. Wetherbee, A. C. Townsend, E. W. Branch, W. H. Paterson, A. A. Adams and E. C. Frost.

June 4, 1904; excursion to the sewage disposal works at Framingham and Worcester; 33 members present.

October 12, 1904; regular meeting; 52 persons present. Paper by M. N. Baker, entitled "A Recent Visit to Twenty-Four British Sewage Works." Discussed by L. P. Kinnicutt, H. W. Clark and others.

January 4, 1905; regular meeting; 40 persons present. Paper by F. A. Barbour, entitled "The Sewage Disposal Works at Saratoga, N. Y." Discussed by D. C. Moriarta and others.

February 1, 1905; regular meeting; 55 persons present. Paper by W. C. Parmley, on "The Use of Concrete in Sewer Construction." Followed by a general discussion.

The maximum number present at any of the meetings has been 120, the minimum number 40 and the average 71. We find from the last annual report of the Board of Government of the Boston Society of Civil Engineers that with a membership of nearly 600, the maximum attendance at the meetings was 130, the minimum 35 and the average 81. This comparison is introduced to indicate the interest taken in the meetings of the Section.

The policy of holding a dinner previous to the meeting has, so far, proved to be a wise one. It has stimulated sociability at the meetings, and it has especially attracted the out-of-town members, who at all of the meetings have been well represented. The desirability, however, of having permanent quarters in a building where dinners can be served is very obvious. With the Society in such a house, opportunity for social intercourse would be still further increased and the expense of the dinners would be reduced very materially. It is to be hoped, from the standpoint of the Sanitary

Section at least, that the present agitation in regard to new quarters for the Society may result in obtaining such accommodations.

The papers and discussions presented at the meetings have been eminently practical, and those at the two meetings devoted to the cleaning and flushing of sewers have brought out a great number of points of practical experience in the maintenance of sewerage systems which are not found in the text-books or other publications, and the information obtained at these meetings alone would justify the establishment of the Section. A stenographer has been present at every meeting and all of the papers and discussions have been or are to be printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

The Committee on Uniform Statistics of Sewer Construction and Maintenance, although not yet ready to report, has nearly perfected a scheme for uniform accounts, which, if adopted by the Section, will be of great service to those interested in sewerage systems everywhere.

For the Executive Committee,

WILLIAM S. JOHNSON, *Clerk.*

BOSTON, MASS., MARCH 15, 1905.—The annual meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., President Frederick Brooks in the chair. Sixty-two members and visitors present.

The record of the last regular meeting was read and approved.

Messrs. Henry P. Drake and James A. Moyer were elected members of the Society.

On motion of Mr. Miner, of the Committee on Excursions, the thanks of the Society were voted to Mr. C. H. Eddy and Mr. F. A. Foss for courtesies extended to the Society this afternoon on the occasion of the visit of members to Chickering & Sons' Piano Factory.

The Secretary reported for the Board of Government that it had investigated the project for the consideration of matters of municipal improvement in connection with representatives of several other organizations which was referred to it by the Society at the last meeting. The Board thinks that under the present circumstances it is inexpedient for the Society as a body to take any action. The report was accepted.

The Secretary read the annual report of the Board of Government and, on motion, it was accepted and placed on file.

The Treasurer read his annual report and, on motion, it was accepted and placed on file.

The Secretary read his annual report, which was also accepted and placed on file.

Mr. Adams, for the Committee on Excursions, read the annual report of that committee, which was accepted and placed on file.

The Librarian read the annual report of the Committee on the Library, which was accepted and placed on file.

Mr. E. W. Howe made a verbal report for the Committee on Advertisements.

The Committee on Quarters submitted its report in print, which was read by its Secretary, Mr. W. S. Johnson.

Mr. A. H. Howland objected to receiving the report because he did not consider that the Society had authorized the Board of Government in reappointing the committee to increase the number of its members. The President ruled that the Society could receive the report, and, upon an appeal being taken from the ruling, the Chair was sustained. Mr. E. W. Howe stated that he did not concur in the recommendation contained in the report of the committee. On motion, it was then voted to accept the report and place it on file.

The tellers of election, Messrs. Clifford Foss and Frank T. Daniels, submitted the result of the letter ballot, and, in accordance with their report, the following officers were declared elected:

President—John W. Ellis.
Vice-President (for two years)—Freeman C. Coffin.
Secretary—S. Everett Tinkham.
Treasurer—Edward W. Howe.
Librarian—Frank P. McKibben.
Director (for two years)—Edward F. Miller.

A discussion then took place as to sending a copy of the report of the Committee on Quarters to each member of the Society, as to assigning a meeting at which it should be discussed and as to calling for a letter ballot on the matter.

It was finally voted, on motion of Mr. Manley, that the matter of the report of the Committee on Quarters be referred to the Board of Government.

On motion of Mr. McKibben, it was voted to appropriate the sum of $75 for the purchase of standard engineering books, this sum to include the purchase of the "Transactions of the Engineering Congress" held at St. Louis last October.

On motion of Mr. Higgins, it was voted: That the Board of Government be authorized to appoint any standing and special committee that may be needed to properly conduct the business or protect the interests of the Society, and to select the numbers and members thereof.

President Brooks used the occasion of the closing of his term of office to address the Society upon "Some Changes in Arithmetic to Decimal Reckoning." He explained the superseding of the sexagesimal fractional system by decimal fractions in tables of trigonometric functions about 400 years ago, and spoke more briefly of the superseding of pounds, shillings and pence by dollars and cents in the money of the United States during the last century. Referring to the introduction of the metric system of weights and measures still more recently, he proposed to send to the members individually copies of the January, 1905, report of the Decimal Association of London. He spoke of the introduction, as yet only partial, of the centesimal division of arc and angle in place of the ancient sexagesimal subdivision, and he pointed out some of the problems and difficulties which would arise in the attempt to substitute a decimal time-reckoning for the existing customary practice.

Adjourned.

S. E. Tinkham, *Secretary.*

Annual Report of the Board of Government for the Year 1904-1905.

Boston, March 15, 1905.

To the Members of the Boston Society of Civil Engineers:

In compliance with the requirements of the constitution, the Board of Government submits its report for the year ending March 15, 1905.

At the last annual meeting, the total membership of the Society was 528, of whom 518 were members, 2 honorary members and 8 associates. At that time, 4 members of the Sanitary Section had completed their membership. During the year we have lost 18 members: 6 by resignation, 6 by forfeiture of membership for non-payment of dues, and 6 by death. There have been added to the Society during the year 67 new members. The present membership of the Society consists of 2 honorary members, 12 associates, and 563 members, a total of 577. Eleven new members have been added to the Sanitary Section during the year. The total membership of the Section is 149, of whom 134 are members of the Society and 15 have membership in the Section only.

The record of deaths during the year is Charles W. Folsom, died May 19, 1904; Kilburn S. Sweet, died July 15, 1904; Reuben Shirreffs, died August 31, 1904; James T. Boyd, died November 3, 1904; Macy S. Pope, died December 10, 1904; Charles M. Wilkes, died January 7, 1905.

Ten regular meetings of the Society have been held during the year, and the Twenty-third Annual Dinner was given at the Hotel Vendome on February 28, 1905. The average attendance at the regular meetings was 84; the largest being about 200, and the smallest 19. The number at the annual dinner was 126.

At the regular meetings the following papers have been read:

March 16, 1904.—President Ira N. Hollis, address on "Some Data on Marine Engines."

April 20, 1904.—Mr. W. L. R. Emmet, "The Steam Turbine in Modern Engineering." (Illustrated.)

May 18, 1904.—Mr. Stephen Child, "Landscape Architecture." (Illustrated.)

September 21, 1904.—Mr. Sanford E. Thompson, "The Strength of Concrete." (Illustrated.)

October 19, 1904.—Mr. F. W. Hodgdon, "Boat Harbors on the South Coast of Massachusetts." (Illustrated.)

Mr. John E. Cheney, "Construction of the New Cambridge Bridge." (Illustrated.)

November 16, 1904.—Memoir of Charles W. Folsom.

Mr. Desmond FitzGerald, lecture on "The Philippines." (Illustrated.)

December 21, 1904.—Mr. Nelson Spofford, "Massachusetts' Northern Boundary."

Prof. L. J. Johnson, "Some Data on the Weight of a Crowd of People." (Illustrated.)

Memoir of Kilburn S. Sweet.

January 25, 1905.—Mr. Irving E. Moultrop, "The Steam-turbo Generator Station of the Edison Electric Illuminating Co." (Illustrated.)

Memoirs of James T. Boyd, Reuben Shirreffs and Macy S. Pope.

February 15, 1905.—Mr. D. A. Harrington, "Underground and Submarine Conduits for Electric Wires." (Illustrated.)

Six informal meetings have been held in the Society's library during the past year. The subjects discussed at these meetings have been as follows:

May 4, 1904.—Mr. J. Emery Harriman, Jr., "Mechanical Flight."

November 30, 1904.—Mr. William Parker, "Abolition of Grade Crossings in East Boston."

December 7, 1904.—Mr. J. Parker Snow, "Recent Work in Unifying Specifications for Engineering Materials."

January 11, 1905.—Messrs. F. O. Whitney, F. M. Miner and Henry Manley, "The Adjustment of Curb Grades and Paved Surfaces at Street Intersections."

January 18, 1905.—Mr. J. H. Kimball, "The Extension of Trunk Sewer in Newton Highlands under the Cochituate and Sudbury Aqueducts."

February 8, 1905.—Mr. Charles F. Morse, "Concrete Wall on Lynn Shore Reservation."

It will be remembered that about a year ago a Committee of this Society made recommendations with regard to the amendment of the Boston building laws, which recommendations were approved by vote of the Society. They have subsequently been adopted by the Commissioners, to whom the subject was referred, and have been reported by those Commissioners to the Massachusetts Legislature, before whom the matter is now pending.

Our Sanitary Section has continued its vigorous life throughout the year. It has a large membership, and has held more meetings than required by its by-laws, and they have been well attended. Its papers and discussions have been valuable and constitute a large addition to the contents of the JOURNAL of the Association. With regard to the effect upon our finances, the initiation fees of fifteen members admitted to the Sanitary Section, and not otherwise connected with the Society, have added \$75 to our assets. On the other hand, some expense has been incurred for holding its meetings. Hiring a place of meeting is an expense to be expected. When the meetings are held in connection with a dinner paid for by the members of the Section, it is thought reasonable that an allowance from the Society's treasury should be made representing what it would have cost merely to hire a hall. Hitherto, however, it has happened that nothing has been paid for hiring a place of meeting for the Sanitary Section. Its principal cost thus far has been \$103.50 for stenographic reporting. It is believed that more economical arrangements can be made in the future, but, so far as occasion may require, the reporting of technical information is believed by this Board to be one of the most useful purposes to which the money of the Society can be applied.

With regard to the financial condition of the Society, there has been a gratifying increase in the permanent fund from the initiation fees of new members, amounting in all to \$725. On the other hand, our current funds have diminished, the receipts during the past year having been less than the expense by about \$154. This deficit would have been much larger except for the income received from advertisements in the JOURNAL. Omitting this income, there has been for the past four years a reduction in each year of the cash balance of income over receipts. During the year, about \$300 has been received from advertisements. Under the present rules, 70 per cent. of the amount received for advertisements obtained by our Society comes into the

Society's treasury. It seems as if a large increase of advertising might be obtained by an effort among our members, which would be an important factor in the solution of our financial questions. Among the things that have contributed to this undesirable state of affairs has been an increase in the cost of the JOURNAL, amounting to $412 over that of the preceding year; this larger expense is liable to continue. Another thing has been the alteration in our by-laws, by which the new members coming in have not paid dues for the remainder of the fiscal year after their election. The effect of this upon the comparison between successive years is temporary, being an incident of starting the new *régime*. The new members will in the coming year be liable, of course, for regular dues. It may be seen, however, even from the accounts of a year ago that the Society's business is being conducted with such a narrow margin as to its current funds that unless we make a change of policy we cannot venture upon any undertaking requiring extra expenditure of current funds.

The lease of the rooms now occupied by the Society expires on the 1st of June next, and it will be necessary for the Society to take some action before that time upon the question of renewing it. The consideration of it may naturally be connected with the report of the Committee on Quarters, which has been studying it during the past year.

Fifty dollars was appropriated for the purchase of new books for the library during the year, but only about $30 has been expended. The Board recommends that for the coming year an appropriation of $75 be made for that purpose. The reason for the increase is that it is expected that an expenditure of about $30 will be required to purchase and bind the Proceedings of the International Engineering Congress, held last October at St. Louis.

The number of badges issued to members of the Society has now reached 169.

As authorized by a vote of the Society, cards of introduction to the rooms of Engineering Societies in a number of different cities have been prepared. They have been issued by the Secretary to such members as have applied for them, and to new members as they have joined the Society, and they are to be sent to the remaining members of the Society very shortly.

Last spring it was left to the Board of Government to make such arrangements as might prove desirable for extending hospitality to foreign engineers, of whom a great many were expected to visit this country in connection with the Louisiana Purchase Exposition. Though occasion did not arise for the entertainment by our members of any large number of persons in a body, there were numerous visitors from abroad, who came singly or in small parties during the summer and fall, and many courtesies were extended to them by members of this Society, for which gratifying expressions of appreciation were made by the visitors.

An important event in the business of the Association of Engineering Societies is the resignation of Mr. John C. Trautwine, Jr., who has served as the Secretary of the Board of Managers of the Association for eleven years. The Boston Society of Civil Engineers has always been deeply interested in the Association, and its Board of Government wishes to put upon record an expression of its appreciation of the great value of his energetic and skillful service.

For the Board of Government,

FRED. BROOKS, *President.*

Abstract of the Treasurer's and the Secretary's Reports for the Year 1904-1905.

CURRENT FUND.

Receipts:

Dues for 1904-1905	$3,463.50	
Dues for 1905-1906	28.00	
Sales of Journals	5.25	
Rent of rooms	1,000.00	
Advertisements in the Journal	457.52	
Interest on deposits	14.43	
Repayment from Permanent Fund	169.43	
Balance on hand, March 17, 1904	441.39	
		$5,579.52

Expenditures:

Rent	$1,650.00	
Association of Engineering Societies	1,449.00	
Printing and postage	644.57	
Salaries of Secretary, Librarian and Custodian	550.00	
Commission on advertisements	154.90	
Reporting meetings	141.00	
Incidentals	135.53	
Stereopticon	100.00	
Library maintenance	90.82	
Periodicals	62.55	
Binding	57.60	
Lighting	31.69	
Books	30.53	
Furniture and repairs	25.00	
		5,123.19

Balance on hand, March 15, 1905	$456.33
Amount to credit of Current Fund, March 17, 1904	610.82
Excess of expenditures over receipts	$154.49

PERMANENT FUND.

Receipts:

Merchants' Co-operative Bank	$1,218.69	
Sixty-seven entrance fees, Society	670.00	
Eleven entrance fees, Sanitary Section	55.00	
Interest on deposits, savings banks	251.19	
Subscription to Building Fund	100.00	
Interest on bond	36.00	
		$2,330.88

Expenditures:

Dues on shares Merchants' Co-operative Bank	$300.00	
Dues on shares Volunteer Co-operative Bank	300.00	
Dues on shares Workingmen's Co-operative Bank	300.00	
Paid Merchants' Co-operative Bank for old shares transferred	260.25	
Repaid Current Fund	169.43	
Deposited in Provident Institution for Savings	46.11	
Deposited in Boston Five-cents Savings Bank	43.01	
Deposited in Eliot Five-cents Savings Bank	41.25	
Deposited in Warren Institution for Savings	40.73	
Deposited in Institution for Savings in Roxbury	40.24	
Deposited in Franklin Savings Bank	39.85	
		1,580.87
Balance on hand, March 15, 1905		$750.01

PROPERTY BELONGING TO THE PERMANENT FUND, MARCH 15, 1905.

Twenty-five shares Volunteer Co-operative Bank	$3,726.00
Twenty-five shares Workingmen's Co-operative Bank	3,372.89
Twenty-five shares Merchants' Co-operative Bank	1,795.79
Deposit in Provident Institution for Savings	1,352.94
Deposit in Boston Five-cents Savings Bank	1,261.84
Deposit in Eliot Five-cents Savings Bank	1,210.17
Deposit in Warren Institution for Savings	1,194.68
Deposit in Institution for Savings in Roxbury	1,180.51
Deposit in Franklin Savings Bank	1,168.92
One Republican Valley R. R. Bond, No. 2 (par value)	600.00
Cash on deposit in Old Colony Trust Company	750.01
	$17,613.75
Amount as per last annual report	16,080.54
Increase during the year	$1,533.21

TOTAL PROPERTY OF THE SOCIETY IN THE POSSESSION OF THE TREASURER.

Permanent Fund	$17,613.75
Current Fund	456.33
Total	$18,070.08
Amount as per last annual report	16,691.36
Total increase during the year	$1,378.72

Report of Committee on Excursions.

Boston, March 15, 1905.

To the Members of the Boston Society of Civil Engineers:

The Committee on Excursions submits herewith its annual report.

Eleven excursions have been made during the year, as follows:

April 20, 1904.—Edison Electric Illuminating Company's L Street Station. Attendance, 27.

May 18, 1904.—South Terminal Station. Attendance, 16.

June 15, 1904.—Power plant, Jordan-Marsh Company, and press rooms of *Boston American*. Attendance, 11.

July 20, 1904.—Road across Lynn Marsh, under construction by the Massachusetts Highway Commission. Attendance, 33.

September 29, 1904.—Sewerage Works at Nut Island and the Calf Pasture Sewage Pumping Station. Attendance, 39.

October 19, 1904.—New Cambridge Bridge. Attendance, 55.

November 17, 1904.—United Shoe Machinery Company's plant at Beverly, Mass. Attendance, 32.

December 14, 1904.—Abolition of grade crossings of the Boston & Albany R. R. at East Boston. Attendance, 25.

January 12, 1905.—South Boston Station, Edison Electric Illuminating Company. On account of the unusually severe storm, there was no attendance.

February 15, 1905.—General Electric Co.'s Works at Lynn.

March 15, 1905.—Chickering & Sons' Piano Factory. Attendance, 17.

Total attendance, 332; average attendance, 30.

Eighteen pages of the *Bulletin of Engineering Work* have been published during the year. The committee wishes to thank those who have aided in this work.

There is a cash balance of $34.35 in the hands of the Treasurer.

Respectfully submitted,

Franklin M. Miner, *Chairman*,
Edward P. Adams, *Sec'y and Treas.*,
Edward F. Miller,
Walter H. Norris,
Frank E. Winsor,
Committee on Excursions.

Report of the Committee on the Library.

Boston, March 15, 1905.

To the Members of the Boston Society of Civil Engineers:

The Committee on the Library begs leave to make the following report for 1904-1905:

The Committee has suffered a great loss in the death of Mr. Kilburn S.

Sweet, who, for several years before his death, devoted a great deal of time and attention to the details of the library. The improvement in the arrangement of the government reports in the library is due almost entirely to his efforts.

There have been received and accessioned since the last annual meeting, 190 bound volumes, which is slightly more than one-half as many as were received during the preceding year. If as many books had been received during the past year as were received in the year 1903-1904, it would have been impossible to find room enough for them upon the shelves of the library.

As indicated in the previous report of the Library Committee, the question of shelf room for books is a very serious one. At present most of the shelves contain two rows of books, and there are on hand several volumes stored away in cupboards which should be placed upon the shelves, but for which there is not room. When the next lot of books are received from the binder, it will be necessary to provide more shelf room.

The Committee wishes to recommend that the practice of purchasing standard engineering books for the library be continued for the coming year.

Respectfully submitted,

FRANK P. MCKIBBEN,
J. N. FERGUSON,
R. S. HALE,

Committee on the Library.

Montana Society of Engineers.

THE regular meeting of the Society was held in the Society room Saturday, March 11, at the usual hour, Vice-President B. H. Dunshee presiding, a quorum being present. The minutes of the previous meeting were read and approved. The applications of Messrs. Moran and Wisner for membership were read by the Secretary, approved, and by motion the necessary ballots were ordered sent out. Messrs. Humphry, Keller, Leimer and McLeod were elected to membership by a unanimous vote. The Trustees reported that they had examined the books of the Secretary and Treasurer and found them correct, and on motion the report was approved. The matter of withdrawal from the Associated Societies, made a special order for this meeting, was called up, and indefinitely postponed without a dissenting vote.

The Secretary was instructed to correspond with the Secretary of the American Society of Civil Engineers and inquire if this Society can make arrangements to have the publication of that Society distributed among the members of the Montana Society of Engineers and on what terms.

A. H. Weithey and George W. Wilson read papers on the theme "United States Mining Laws," which has been before the Society for consideration for some time. Quite a lengthy discussion followed, after which the Society adjourned.

CLINTON H. MOORE, *Secretary.*

Engineers' Club of St. Louis.

595TH MEETING, ST. LOUIS, MO., MARCH 15, 1905.—Held at the Club Rooms, 3817 Olive Street, Wednesday evening, March 15, 1905, Vice-President Layman presiding. There were present thirty-nine members and nine guests.

The minutes of the 594th meeting were read and approved, and the minutes of the 386th meeting of the Executive Committee were read.

An application for membership in the Club was read from Oddgeir Stephensen.

Mr. Chas. Adams Homer was elected a member of the Club.

A very interesting paper was presented by Mr. Lionel Viterbo upon "Fundamental Principles of Reinforced Concrete." The paper was discussed at length by Messrs. A. L. Johnson, Henby, Ockerson, Russell, Humphrey and Viterbo.

The Secretary announced as the paper for the next meeting "The Levee and Drainage Problem of the American Bottoms," by Mr. E. G. Helm.

Adjourned.

R. H. FERNALD, *Secretary.*

Association of Engineering Societies.

Vol. XXXIV. **APRIL, 1905.** No. 4.

PROCEEDINGS.

Toledo Society of Engineers.

Toledo, Ohio, March 7, 1905. — In November, 1903, Messrs. G. V. Rhines, C. A. Raymond and S. D. Bullock discussed the question of an Engineers' Society in Toledo. After consulting Mr. H. E. Riggs several preliminary meetings were held, resulting in an organization, and the adoption of a constitution and by-laws on January 8, 1904, at which time officers were elected for the year by a membership of forty-seven. During the year twenty-four additional members were received. One death has occurred, and one resignation, leaving the membership of sixty-nine on January 1, 1905. During the year papers were read, discussed, and often illustrated with maps, photos and diagrams on the following subjects:

" Panama Canal," " Lake Erie and Ohio River Ship Canal," " Safe Construction of Theaters," " Toledo Railway and Terminal Belt," " Modern Methods of Paving Streets," " Disposal of Municipal Refuse," " Lighting of Mill Buildings," " Crane Service in Mill Buildings," " Reinforced Concrete," " Reinforced Concrete Warehouse," " The Eads Bridge," " Repairs and Reinforcing." A lecture was given in the Grand Theater upon the Isthmian Canal by Mr. W. V. Alford of Columbus, illustrated by many excellent lantern slides. A trip to the Toledo Blast Furnace completes the schedule of the work done by the Society during 1904.

Two of the papers referred to, " Safe Construction of Theaters," by Mr. E. O. Fallis, and " Disposal of Municipal Refuse," by Mr. F. K. Rhines, were published in the Journal of the Association of Engineering Societies.

John C. Oliphant, *Secretary.*

Engineers' Club of St. Louis.

594th Meeting, St. Louis, March 1, 1905. — Held at the Club rooms, 3817 Olive Street, Wednesday evening, March 1, 1905, President Flad presiding. There were present forty-one members and four guests.

The minutes of the 593d meeting were read and approved, and the minutes of the 385th meeting of the Executive Committee were read.

Application for membership in the Club was read from Charles Adams Homer.

The following were elected to membership in the Club: George Waters Arnott, William Ralph Busch, William H. Elliot, Elmer C. Peper.

A paper of unusual interest by Mr. Carl Gayler on "Our Grade-Crossing Problems" drew out a large attendance of the Club members, and provoked lively discussion by Messrs. Cunningham, Rohwer, Valliant, Phillips, Zeller, Pfeifer, McCulloch, Flad, Greensfelder, Bryan and Gayler.

Adjourned.

R. H. Fernald, *Secretary.*

596th Meeting, St. Louis, April 5, 1905. — Held at the Club rooms, 3817 Olive Street, Wednesday evening, April 5, 1905, President Flad presiding. Twenty-eight members and seven guests were present.

The minutes of 595th meeting were read and approved. The minutes of the 387th meeting of the Executive Committee were read.

Applications for membership were read from Holger Stuckmann, John Taylor, Douglas Turner.

Mr. Brenneke, chairman of the Entertainment Committee, announced an excursion for the Club members for Saturday, April 15, to the plant of the Atlas Cement Company, near Hannibal, Mo.

The plan is to leave St. Louis about 8 a.m., returning about 7 p.m. Luncheon will be served at the works. There will be a Pullman on the train with buffet, etc. The total expense will be $1.00 per member.

Mr. Greensfelder moved that the Executive Committee be instructed to make application for membership in the Million Club of St. Louis. The motion was seconded. After a brief discussion, Mr. Russell moved that the matter be laid over until the next meeting. Seconded by Mr. Bryan. The motion was carried. It was moved by Mr. Brenneke that the Executive Committee investigate this matter and report at the next meeting. The motion was carried.

The Secretary read a letter from Mr. W. R. Bascome stating that he had sent to the Club specifications of the Williamsburg Bridge in New York City. The Secretary stated that he had acknowledged the receipt of the same, expressing the thanks of the Club for the donation.

Mr. Helm's interesting paper upon "The Levee and Drainage Problem of the American Bottoms" was ably presented. After discussion of the paper by Messrs. Pitzman, Russell, Moon, Bryan and Helm, the meeting adjourned.

R. H. Fernald, *Secretary.*

597th Meeting, St. Louis, April 19, 1905. — Held at the Club rooms, 3817 Olive Street, Wednesday evening, April 19, 1905, President Flad presiding. Thirty-eight members and twenty-two guests were present.

The minutes of the 596th meeting were read and approved. The minutes of the 388th meeting of the Executive Committee were read.

The following letter from the Hunkins-Willis Lime and Cement Company was read:

April 18, 1905.

Mr. R. H. Fernald, Secretary Engineers' Club of St. Louis,
3817 Olive Street, City:

Dear Sir, — We acknowledge receipt of your favor of the 16th enclosing list of members of the Engineers' Club and guests who visited

the plant of the Atlas Portland Cement Company on Saturday last. It is very gratifying to us to learn that the trip was a pleasant one to your members and it is our earnest hope the information derived will be of benefit. If you feel that the time spent at the plant was not sufficient to obtain all that you desired, we will be glad to arrange a similar trip at a later date.

Yours truly,
HUNRINS-WILLIS LIME AND CEMENT COMPANY,
By GORDON WILLIS, *Vice-President.*

Upon motion of Mr. Robert Moore a hearty vote of thanks was extended the Hunkins-Willis Lime and Cement Company, and to the Entertainment Committee for securing and arranging the trip. The Secretary was instructed to send letters in accordance with this action.

The following were elected members of the Club: Holger Stuckmann, John Taylor, Douglas Turner.

The Executive Committee reported in favor of having the Club join the Million Club. After discussion by Messrs. Robert Moore, Greensfelder, Thacher and Flad, Mr. Philip Moore moved that the question be indefinitely postponed. Carried.

A very profitable evening was then spent in listening to the brief talks upon "Coal Investigations at St. Louis." The meeting took the form of an informal *Smoke Talk.* The subject was outlined as follows:

"Importance to Engineers of St. Louis," Messrs. Arthur Thacher, Robert Moore, Wm. H. Bryan; "General Plan of Fuel Investigations by the United States Geological Survey," Mr. J. A. Holmes; "Steaming Tests," Mr. W. T. Ray; "Producer-Gas Tests and Gas Engines," Mr. R. H. Fernald; "The Coals to be Tested — Sampling and other Problems," Messrs. E. W. Parker, J. S. Burrows; "Improvement in Quality of Coals by Washing," Mr. J. D. Wick; 'Plans for Chemical Work," Mr. E. E. Sommermeier.

Much enthusiasm in the work of the United States Geological Survey Coal Testing Plant was awakened by the meeting.

Adjourned.

R. H. FERNALD, *Secretary.*

Civil Engineers' Club of Cleveland.

25TH ANNIVERSARY BANQUET, HELD MARCH 13, 1905. — One hundred and forty members of the Club and their friends assembled at the Colonial Hotel at eight o'clock Monday evening, March 13, to celebrate the Club's twenty-fifth birthday. After a pleasant half hour spent in renewing old acquaintances and meeting new ones, attention was given to a very satisfying exhibition of the culinary capacity of the hotel's chef. This having been disposed of, President Alex. E. Brown, as toast master, assumed the direction of affairs.

First on the program was the rendering of "Clouds" and "Sunshine," both by Schilling, by the Ionic Quartet.

Mr. Trautwine, being unable to be present, sent a very interesting letter in response to the toast, "Our Faithful Guardian of the Engineers' Trust, whose ever-full pocketbook has given unlimited aid to the needy engineer," in which he gave a brief outline of the founding of the Asso-

ciation of Engineering Societies and painted a glowing picture of its future as a publication medium for the engineering societies of the country.

Letters of regret from General Paine and Gen. John M. Wilson, and telegrams from Professor Michelson and Gen. J. A. Smith were also read.

Mayor Tom L. Johnson responded to the toast, " Our Mayor, Retired Engineer and Manufacturer, always interested in engineers and their work, has never forfeited his title to be one of us," in the course of which he first gave to the world his scheme for rapid transportation by means of an electric " slide " with which he proposes to reduce the time from New York to Chicago to two hours.

Mr. W. R. Warner, sixth president of the Club, responded to the sentiment, " Our Manufacturer of Long-Distance Glasses," with which he determined the orbit and predicted the advent of a great sea-level canal in " Other Worlds than Ours."

Mr. Jos. Leon Gobeille, eighth president, then told some very witty reminiscences of the production of " the " book and also some other things in responding to the toast " Our Bookmaker, whose pattern shows the mark of wisdom."

Mr. Walter P. Rice, ninth president, responded to " Our Present Historian and Original Architect, who first drew the plans of our Club to the Metric Scale," supplementing his work in the book by a more detailed account of the efforts of the original three.

" Rare Bits of History," an historical poem by an unknown historian, was read with great effect, at this point, by Professor Benjamin.

Bits of Unwritten History.

In eighteen hundred eighty,
  On the thirteenth day of March,
Was the beginning of things weighty,
  Which this night we celebrate.

But it isn't common knowledge,
  That is, not to every one,
How this smart Association
  In the beginning was begun.

In the earlier days of eighty
  Than the one we celebrate,
Three wise young men of promise
  Began to meditate.

Each had his own convictions,
  And had followed them for years,
One was a good surveyor,
  And two, good engineers.

Individual opinions
  Were as solid as a rock,
Still, it might be best to bunch them,
  And take account of stock.

One was a land surveyor,
  First name begins with C —
He must never be mistaken
  For the older " Moses C."

Another of this trio,
  Though a prophet in his way,
Should never be confounded
  With the ancient Hosea.

There was one more in this trio,
  You'll recall his name perhaps,
If you've ever been invited
  To a dinner with the Japs.

When they once got down to business,
  They were sure it would be found
That this lovely combination
  Covered nearly all the ground.

Where was there in all creation
  Found a problem so profound
That surveyors cannot measure,
  And no engineer can sound?

They were anti-anti-metric,
  That is, *metric* (in their mind),
But whene'er they came to measure,
  Each one used the other kind.

When at last they came together,
  They soon found, to their amaze,
That each man had been invited
  To join the anti-metric craze.

But each had said, " Not any;
  We are not built that way;
The meter is our motto
  And we're ready for the fray."

Being burdened with spare moments,
  They looked about a bit,
For some chip upon the shoulder,
  On which to make a hit.

They found some anti-metrics,
  Who had organized a class
To study the Great Pyramid;
  This the trio could not pass.

Said this anti-metric business
  Should be sat on good and hard:
" We're the very ones to do it,
  And can do it by the card."

When they'd weighed their ammunition,
And had counted up their men,
They found they lacked just seven
Of the metric number *ten.*

It was then they felt quite lonely,
For they said " 'Twould never do,
To attack these anti-metrics
With so very small a crew."

In the highways and the byways,
They besought for seven more,
Who would swear by the great *meter*—
Never mind what else they swore.

Then with ready rhyme or reason,
Specious arguments they bring,
" If you'll just adopt our measure
You can meter everything."

" You can meet her in the garden,
You can meet her out at tea,
It will be a Water Meter
When you meet her by the sea."

" You can meet her once, or often,
You can meet her where you will,
But 'twill be a *millimeter,*
When you meet her by the mill."

" It is not a *centimeter,*
Nor the best of sentiment,
If each time you're asked to treat her,
You refuse to spend a cent."

" With its magic you can measure,
Liquids — solids — gases — ground,
But apply it to your lightning,
And you'll hear the wheels go round."

Thus with logic quite conclusive,
They beguiled these innocents;
Thus the seven they were after
Yielded to their blandishments.

But their field began to broaden,
As their numbers came and went,
Thus the *meter* seemed to shorten,
Or was less belligerent.

Then organized their forces
On a somewhat broader plane;
With their future all before them,
Excepting as to name.

For they said, " It is not certain,
  Just what we want to be;
We've so multiplied our numbers,
  By the simple *rule of three.*

"It was our first impression
  That we were called and sent
To oppose these anti-metrics,
  As our first and sole intent.

" We thought we were born soldiers,
  Three full-fledged brigadiers,
But we have about concluded
  We are better engineers."

It was then they called a meeting,
  On this vastly broader plan;
March the thirteenth, eighteen eighty,
  Marks the date this Club began.

It was this initial meeting
  Gave this goodly Club its name;
Gave it officers and standing,
  Blazed the trail by which it came.

This was how the matter started,
  This is how the matter grew;
How an energetic trio
  Builded better than they knew.

Praise be to these gentle heroes,
  Praises go where they belong;
Praises yield them, while you're waiting,
  For this *finis* to my song.

The quartet rendered an original song entitled " Memories," written especially for this occasion, to the air of " Annie Laurie."

MEMORIES.

(Air, " Annie Laurie.")

We like to talk of old times,
  Of comrades past and gone;
To us they seem the best times
  That e'er the sun shone on.

CHORUS.

And spite of wind and weather,
  As heart to heart draws night,
We'll merrily sup together
  And talk of days gone by.

So let us talk of Holloway,
Of Latimer and Paul,
With now a thought for others
Too near by name to call. — CHORUS.

But though our comrades left us
And passed beyond our ken,
Their works abide forever,
The works of faithful men. — CHORUS.

A score and five of years gone,
And now the present pleads:
" God grant the coming cycle
May show like men and deeds." — CHORUS.

Mr. Ambrose Swasey, eleventh president, told us something of his travels in responding to " Our Globe-trotter and Explorer of our Insular Possessions — the Man of Granite, Engineer and Accomplishment."

Dr. Chas. S. Howe, thirteenth president, brought news of inter-stellar space as a response to the toast " Our Science President, who often returns loaded down with rare game, unknown to the common herd, from his favorite hunting grounds, the sunny hills and cool shadowed valleys of the moon."

Ionic Quartet, Nocturne, Protheroe.

Prof. Chas. H. Benjamin, eighteenth president, responded to " Our Manufacturer of Mechanical Engineers, — the Enemy of Smoke and Buster of Fly-Wheels," but didn't tell how he abolished smoke, presumably because the lateness of the hour, 1 A.M., precluded extended remarks.

MARCH 14, 1905. — The annual meeting was held in the rooms of the Club, and was called to order by the Secretary, Mr. W. O. Henderer, being then elected temporary chairman.

Messrs. Hoffman and Horner, tellers, reported the following officers elected for the ensuing year:

President — Bernard L. Green, C.E.

Vice-President — Dayton C. Miller, A.M., D.Sc.

Secretary — Joseph C. Beardsley.

Treasurer — Arthur G. McKee, M.E.

Librarian — Elmer B. Wight.

Directors — Col. Dan C. Kingman, U. S. A., Charles H. Wright.

Messrs. T. M. Brown and J. E. A. Moore, tellers, reported the election of the following to membership in the Club:

As Active Members: Heinrich J. C. Freyn, Harold Arthur Gilbert, Frank E. Hulett, F. J. Littell, Charles H. Little, Franklin Moeller, Harry Elihu Scott, Warren H. Thompson.

As Associate Member: George N. Pifer.

As Corresponding Member: Ralph Switzer Moore.

The following applications for membership, approved by the Executive Board, were read: George F. Burrows, Robert H. Clifford, Frederick A. Coleman, James B. Green, Robert P. Greenleaf, David Gutman, J. Frank Morse, George A. Peabody, Eugene C. Peck, Alexius R. Pribil,

Robert E. Sheal and Frederick H. Sibley; and for transfer from the Boston Society of Henry W. Fenno, all for active membership.

For associate membership, Robert C. Dodd.

Annual reports of the Secretary, Treasurer, Librarian and Program Committee were read and ordered received and filed.

Report of the Secretary, Year Ending February 28, 1905.

Financial.

PERMANENT FUND.

Balance, March 1, 1904		$1,627.38	
Fees	$160.00		
Interest	66.31		
		226.31	
		$1,853.69	
Transferred to General Fund		565.00	
Balance, February 28, 1905			$1,288.69

LIBRARY FUND.

Balance, March 1, 1904		$78.82
Disbursements	$68.62	
Transferred to General Fund (error 1903)	10.20	
		$78.82

GENERAL FUND. — RECEIPTS.

Balance, March 1, 1904		$58.60
Dues, Active	$1,550.00	
Associate	96.00	
Corresponding	117.50	
Delinquent	158.00	
1905 (active)	15.00	
Total dues	$1,936.50	
Advertising	51.00	
Contributions, account entertainment	53.00	
Contributions, account new quarters	109.00	
Library Fund (error in 1903)	10.20	
Permanent Fund, transfer	565.00	
		2,724.70
		$2,783.30

DISBURSEMENTS.

Printing	$120.50
Stationery and postage	193.68
Entertainment	186.25
Associated Tech. Clubs	792.00
Assoc. Engineering Soc. Journal	528.05
Secretary	200.00
New quarters (subscription)	109.00
Taxes	29.55
Furniture	23.75
Collection, delinquent dues	20.10

Library	$11.68		
Incidentals	14.50		
1903 Bills — Printing, $5.75; Assoc. Tech. Clubs, $198; Assoc. Journal, $216.40; Secretary, $100; Incidental, $11	531.15		
		$2,760.21	
Balance, February 28, 1905		$23.09	

SUMMARY.

March 1, 1904, total balance	$1,764.80		
Total receipts	2,375.81		
		$4,140.61	
Total disbursements		2,828.83	
Total balance, February 28, 1905			$1,311.78

BILLS RECEIVABLE.

From members (dues)	$230.00		
Advertising	11.00		
Subscriptions	4.00		
		$245.00	

Jos. C. Beardsley, *Secretary.*

Report of the Treasurer.

Cleveland, Ohio, March 6, 1905.

To the Civil Engineers' Club of Cleveland, Ohio:

Gentlemen, — The following is my report of moneys handled for the Club during the year ending February 28, 1905:

Balance on hand, February 29, 1904, as per report of former Treasurer,			
Permanent Fund	$1,627.38		
General Fund	58.60		
Library Fund	78.82		
		$1,764.80	
Received by former Treasurer, between February 29, 1904, and March 15, 1904		479.20	
			$2,244.00
Disbursed by former Treasurer, between February 29 and March 15, Gen. Fund — Vouchers 288 to 295 inclusive		$531.15	
Disbursed Feb. and March Library Fund		10.70	
			541.85
Balance			$1,702.15
Received from former Treasurer, March 15, 1904,			
Permanent Fund	$1,627.38		
General Fund	6.65		
Library Fund	68.12		
		$1,702.15	
Received from Secretary up to February 28, 1905,			
On account Permanent Fund		160.00	
On account General Fund		2,136.50	
On account New Quarters contribution		109.00	
On account Interest Permanent Fund		66.31	
Total			$4,173.96

Disbursed General Fund, vouchers 296 to 353 inclusive, including $109 for new quarters		$2,229.06	
Disbursement Permanent Fund — transferred to General Fund		565.00	
Disbursement Library Fund		68.12	
			$2,862.18
Balance			$1,311.78
Balance on hand, February 28, 1905,			
Permanent Fund	$1,288.69		
General Fund	23.09		
Total	$1,311.78		

Respectfully submitted,

ROBERT HOFFMAN, *Treasurer.*

A partial report of the House Committee, Associated Technical Clubs, was also read, in which the items for the current month were estimated, the Committee year ending March 31.

The Secretary read a communication from Mr. C. H. Wright, presenting a fine framed portrait of the retiring President, Mr. Alex. E. Brown, to the Club. The portrait was received, and a vote of thanks tendered the donor.

The question of having the President's address read at a later meeting was discussed and was finally referred to Mr. Wright and Mr. Allen to arrange for a date for its reading.

Adjourned.

JOS. C. BEARDSLEY, *Secretary.*

REGULAR meeting, April 11, 1905.

Meeting called to order by the Vice-President at 8.20 P.M. Present, ninety-five members and visitors.

Minutes of the last meeting read and approved.

The following applications for membership, approved by the Executive Board, were read: For active membership, Willard Beahan, Eugene G. Deucher, Fred. W. Hanks, Harry F. Miter, and for associate membership, Melvin V. Pattison.

The tellers, Messrs. Henderer and Hoffman, reported the election to active membership of the following: George F. Burrows, Robert H. Clifford, Frederick A. Coleman, James B. Green, Robert P. Greenleaf, David Gutman, John Frank Morse, George A. Peabody, Eugene C. Peck, Alexius R. Pribil, Robert E. Sheal, Frederick H. Sibley, and Henry W. Fenno transferred from the Boston Society; and to associate membership of Robert C. Dodd.

Messrs. Honsberg, Hoffman and Fox were announced as a Committee on Introduction.

The following resolution, introduced by the Secretary, was adopted without discussion: "Whereas one of the most serious problems of cities and towns is the rapidly increasing contamination of the sources of water supply: Resolved that a committee of this Club be appointed by the President, to draft legislation to be introduced at the next session of the

legislature, providing for a competent investigation of the pollution of lakes, streams and other sources of water supply."

The paper of the evening was a popular account of the Panama Canal, by Mr. Warner, that was thoroughly enjoyed by all who had the privilege of hearing it.

Adjourned.

JOS. C. BEARDSLEY, *Secretary.*

Adjourned meeting, May 23, 1905.

Meeting called to order by the Vice-President, Dr. Miller, at 8.20 P.M. Present, about eighty members, ladies and other guests.

It being a ladies' night, the reading of minutes of the preceding meeting was dispensed with.

The tellers, Messrs. Rote and W. B. Rawson, reported the election to active membership of the following: Willard Beahan, Eugene G. Deucher, Fred. W. Hanks and Harry F. Miter; and to associate membership, Melvin V. Pattison.

The names of the following applicants for membership, approved by the Executive Board, were read, the reading of the text of the applications being dispensed with: H. Fay Allen, Frederick G. Bates, C. H. Burgess, J. Milton Dyer, Pliny D. Hubbard, Geo. E. Merryweather, Clyde T. Morris, R. B. Perrine, Ralph V. Scott, Geo. H. Tinker, Fred'k J. Trumper, and for transfer from the Boston Society, Lester W. Tucker, all for active membership, and for associate membership, Robert G. Clapp. The paper of the evening, an illustrated description of "The Gold and Diamond Fields of South Africa," was then read by Mr. J. S. Lane, late of Webster, Camp & Lane, and more recently associated with Mr. John Hays Hammond in South Africa.

Refreshments were served after the reading of the paper.

Adjourned.

JOS. C. BEARDSLEY, *Secretary.*

Technical Society of the Pacific Coast.

DIRECTORS' MEETING, SAN FRANCISCO, MARCH 30, 1905. — Held at the San Mateo residence of the President, Mr. George W. Dickie, who had invited the gentlemen of the Board of Directors to take dinner with him.

Present: Directors Manson (for George H. Wallis, deceased), C. B. Wing (for Carl Uhlig), Hermann Barth, H. D. Connick, E. T. Schild, and Otto Von Geldern.

The Secretary notified the members of the death of Director Geo. H. Wallis, and the President appointed a committee consisting of Mr. Rudolph J. Taussig and the Secretary to draw up suitable resolutions of respect in memory of our late colleague and fellow-director.

In the matter of the coming spring meeting, the possibility of holding this meeting in Portland during the Lewis and Clark Centennial was fully discussed, and the Secretary was instructed to communicate with the president of the Exposition, Mr. Henry W. Goode, to ascertain the arrangements that might be made with the authorities for holding pro-

tracted meetings at about the end of June in conjunction with similar societies. A letter to Mr. Goode, dated April 3, 1905, and his reply thereto, dated April 5, 1905, are hereto appended.

Mr. Manson referred to the Pacific Coast Railway Club as one of the organizations likely to take part in an excursion to Portland, and suggested that the Secretary communicate with the Club, suggesting that a committee from the Pacific Coast Railway Club meet a similar committee from the Technical Society for the purpose of considering a joint action in the matter of an Engineering Congress. This was ordered and the Secretary so instructed.

The meeting adjourned to be called again on Friday, April 14, 1905, the members accepting an invitation from Mr. Schild to dine with him on that occasion.

Otto von Geldern, *Secretary.*

Boston Society of Civil Engineers.

Boston, Mass., April 5, 1905. — A special meeting of the Sanitary Section of the Boston Society of Civil Engineers was held at the Copley Square Hotel, Wednesday, April 5, 1905, at 7.30 o'clock P.M.; forty-nine members and guests being present.

A paper was read by C. E. A. Winslow entitled, "A Winter Visit to Some Sewage Plants in Ohio, Wisconsin and Illinois." The paper was fully illustrated with lantern slides and was discussed by Messrs. X. H. Goodnough, R. S. Weston, L. P. Kinnicutt, F. C. Coffin, G. A. Carpenter and others.

In the afternoon about twenty-five members visited the Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology.

William S. Johnson, *Clerk.*

Boston, Mass., April 12, 1905. — A special meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., eighty members being present.

In calling the meeting to order, President John W. Ellis expressed his appreciation of the honor which had been conferred upon him in his election to the presidency of the Society, and thanked the members most sincerely for their consideration.

The Secretary stated that the meeting had been called in compliance with a request of the Board of Government of the Society contained in the following vote: "That the President call a special meeting of the Society on April 12, 1905, to consider the recommendation of the Committee on Quarters and to act on the question of quarters."

Mr. George A. Kimball moved, and it was duly seconded, that it is the sense of this meeting that the report of the majority of the Committee on Quarters be adopted, provided that satisfactory arrangements can be made.

After a very full and earnest discussion of the majority and minority

reports of the Committee on Quarters submitted at the annual meeting, on a vote being taken, the motion was lost, 24 in favor and 41 against.

On motion of Mr. F. P. Stearns it was then voted: "That the Board of Government be authorized to execute a lease with the Tremont Temple Baptist Church."

Adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, MASS., APRIL 19, 1905. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., President John W. Ellis in the chair; thirty-two members and visitors present.

Record of the annual meeting and that of the special meeting of April 12 were read and approved.

Messrs. Robert A. Shailer, Frank E. Shedd, Manuel H. Silvia and Herbert W. Spooner were elected members of the Society.

The Secretary reported, for the Board of Government, the appointment of the following committees:

Committee on Excursions: E. P. Adams, W. H. Norris, L. L. Street, H. R. Stearns and C. T. Fernald.

Committee on the Library: F. P. McKibben, F. I. Winslow, J. N. Ferguson, R. S. Hale and H. K. Barrows.

Committee on Advertisements: E. W. Howe, A. S. Glover and F. V. Fuller.

Members of the Board of Managers, Association of Engineering Societies, in addition to the Secretary, J. R. Freeman, Henry Manley, Dexter Brackett, Dwight Porter and C. W. Sherman.

Mr. H. A. Carson, for the Committee appointed to prepare a memoir of Charles M. Wilkes, submitted and read its report.

Mr. Harold K. Barrows read the paper of the evening entitled, "The Hydrographic Work of the United States Geological Survey in New England, and a Discussion of Methods used for Estimating Stream Flow." The paper was fully illustrated by lantern slides.

Adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, MASS., MAY 17, 1905. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, Boston, at 7.50 o'clock P.M., President John W. Ellis in the chair; seventy-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. Edwin J. Beugler, John H. Gregory and Joseph F. Ross were elected members of the Society.

The Secretary announced for the Board of Government that it had appointed the following Committee on Quarters, Messrs. Desmond FitzGerald, George A. Kimball, E. W. Howe, Wm. S. Johnson and Freeman C. Coffin.

The first paper of the evening was read by Mr. George G. Shedd, entitled, "The Garvins Falls Dam and Water Power Plant."

The second paper was read by Mr. Edward B. Richardson, assistant

engineer for Hollis French and Allen Hubbard, consulting engineers for the Garvins Falls dam, describing the hydro-electrical features of the dam.

Mr. James W. Rollins, Jr., followed, speaking particularly of the construction of the dam from the contractor's point of view.

Both papers were fully illustrated by lantern slides.

After passing a vote of thanks to Mr. Richardson, who is not a member of the Society, for the interesting paper contributed by him, the Society adjourned.

S. E. Tinkham, *Secretary.*

Montana Society of Engineers.

The regular meeting of the Society for April was held Saturday evening, April 8, in the Society rooms at the usual hour. The meeting was called to order by Vice-President Dunshee as soon as the Secretary reported a quorum present. Minutes of the March meeting were read and approved. Under suspension of the rules the applications for membership in the Society of Messrs. Edward K. Triol and Henry C. Bacorn were read, approved and ballots for the same ordered sent out. By a unanimous vote Messrs. Clarence B. Wisner and Wm. J. Moran were elected to membership. A letter was read from the Engineering Society of Seattle, Wash., inviting the Montana Society of Engineers to take part in an Engineering Congress at Portland, Ore., during the Lewis and Clark Fair. The Secretary was instructed to write for particulars.

A communication was read calling attention to some missing Irrigation and Experiment Station papers from the Society Library, and the members were invited to supply the same. The members present had their attention called to a present to the Society of a magnificent picture of the Boston & Montana Company's Smelter at Great Falls, secured through the kind offices of Mr. C. W. Goodale, and on motion a vote of thanks was tendered Mr. Goodale and the givers.

The Society then adjourned.

Clinton H. Moore, *Secretary.*

The monthly meeting of Society for May was held at the Society rooms May 13, at the regular hour, with a large number of members present. Vice-President Dunshee presided, President King being unavoidably absent. After the reading and approval of the minutes of the last meeting the applications for membership in the Society of Messrs. Peter S. Mussigbrod, Alfred Francis Borguis and Frank Osborne Fernald were presented, approved and ballots for the same were ordered circulated. Mr. Edward K. Triol and Henry C. Bacorn were unanimously elected to membership. The Secretary read the announcement of an Engineering Congress to be held at Portland, Ore., June 29 and 30, and July 1, 1905, under the auspices of the Lewis and Clark Exposition, by the Pacific Northwest Society of Engineers and the Technical Society of the Pacific Coast, to which all engineers and technical men are invited. A circular will be issued about June 1 containing list of papers and authors. The Secretary of this Society was instructed to apply for a quantity of the latest circulars

and mail the same with the notices of the June meeting, if possible. The Secretary read a paper by Mr. Jos. H. Harper, wherein the author more clearly defines his position as regards the revision of the United States mining laws. After some little discussion and the reading of an article on the same subject in the April 27th issue of the *Engineering and Mining Journal* by one of the members, the Society adjourned.

CLINTON H. MOORE, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXXIV. **MAY, 1905.** No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

598TH MEETING, ST. LOUIS, MAY 3, 1905. — Held at the Club rooms, 3817 Olive Street, Wednesday evening, May 3, 1905. In the absence of President Flad and Vice-President Layman, Mr. Greensfelder was elected chairman for the evening. Nineteen members and nine guests were present.

The minutes of the 597th meeting were read and approved. The minutes of the 389th meeting of the Executive Committee were read.

Mr. Oddgeir Stephensen was elected a member of the Club.

The illustrated talk by Prof. Holmes Smith of Washington University upon "Refinements of Greek Architecture" was very much enjoyed. After discussion by Messrs. Zeller, Greensfelder and Smith, a hearty vote of thanks was extended Professor Smith for his kindness in presenting his paper before the Club.

Adjourned. R. H. FERNALD, *Secretary.*

599TH MEETING, ST. LOUIS, MAY 17, 1905. — Held at the Club rooms, 3817 Olive Street, Wednesday evening, May 17, 1905, President Flad presiding. Twenty-seven members and three guests were present.

The minutes of the 598th meeting were read and approved. The minutes of the 390th meeting of the Executive Committee were read.

The Secretary read a letter from Mr. Warder, secretary of the Western Society of Engineers of Chicago, relating to a proposed visit of the Engineers' Club of St. Louis to Chicago some time in the near future. The letter was referred to the Entertainment Committee for consideration.

The paper of the evening, by Prof. C. M. Woodward of Washington University, upon "Forces due to Eccentric Weights attached to Rolling Wheels," was presented, and after discussion by Messrs. Perkins, Bryan, Langsdorf, Russel, Bausch, Flad and Hanna, the meeting adjourned.

R. H. FERNALD, *Secretary.*

Association of Engineering Societies.

Vol. XXXIV. **JUNE, 1905.** No. 6.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, Mass., June 21, 1905. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, Boston, at 8 o'clock p.m., thirty members and visitors present. In the absence of the President and Vice-Presidents, Mr. Alexis H. French was chosen chairman of the meeting.

The record of the last meeting was read and approved.

Messrs. Joseph H. Fitch, Joseph H. Libbey, Luis Matamoras and Alexander P. Milnes were elected members of the Society.

Mr. Charles M. Spofford read a paper upon "The Making of Structural Steel," which was illustrated with lantern slides.

The Secretary read a short paper prepared by Prof. John E. Hill, of Providence, describing the Engineering Building recently erected at Brown University. This paper was also illustrated with lantern slides.

Adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

Boston, June 24, 1905. — The regular meeting of the Sanitary Section was held at Point Shirley, Saturday afternoon, June 24, 1905, fifty-eight members and guests being present.

The members were taken to Point Shirley by the Street Department boat *Cormorant*, where a shore dinner was served at the Point Shirley Club. After the dinner a brief business meeting was held, and the members then took the boat for a trip around Boston harbor. Stops were made at the Deer Island sewage pumping station, the outlet of the North Metropolitan sewage system, the Nut Island screen house, the outlets of the high level sewer, the Moon Island sewage reservoirs and the outlet of the Boston main drainage works.

At the business meeting J. W. Bartol, M.D., Charles Harrington, M.D., and George A. Sanborn were elected members of the Section.

The thanks of the Society were voted to the Superintendent of Streets of the City of Boston for the use of the boat of that department and to the officers of the Point Shirley Club for the courtesies extended.

William S. Johnson, *Clerk.*